FOOD TECHNOLOGY

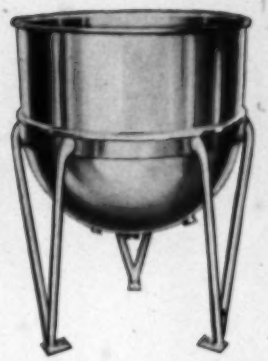
PUBLISHED BY THE INSTITUTE OF FOOD TECHNOLOGISTS

Volume III, Number 8

August, 1949

UNIVERSITY OF MICHIGAN LIBRARIES

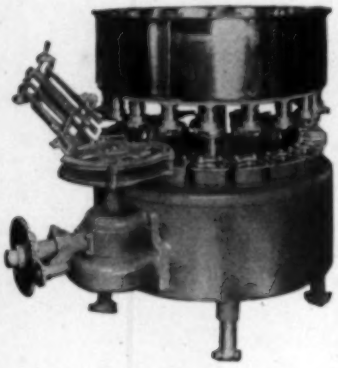
5 Pfaudler food process units with important production advantages

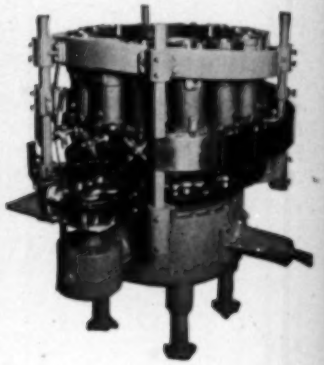


If you pack products which require kettles, fillers, percolators or emulsifiers, these 5 Pfaudler units give you competitive advantages which deserve investigation. Complete details on request.

PFAUDLER STEAM JACKETED KETTLES:

Heat transfer is remarkably fast due to quick circulation of steam through special Pfaudler inlet nozzle. When equipped with agitator (motor driven) and baffles, light to heavy liquids can be quickly mixed and heated without burning-on. Built to ASME code specifications, Pfaudler Kettles may be used for a wide range of operations. Available in 35, 65, 100, 150, 200 and 300 gallons. Three types: stationary, tilting and full jacketed.



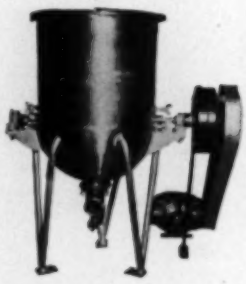


PFAUDLER KING FILLERS:

Two types available—(1) Rotary gravity Can Fillers in five models handle from 50 to 400 No. 1 cans per minute. (2) Rotary Piston Filler—fills liquids, semi-liquids and semi-solids up to 350 to 400 No. 2 cans per minute. Each type of machine fills accurately and speedily. All contact parts sanitary in design and construction. All working parts fully enclosed.

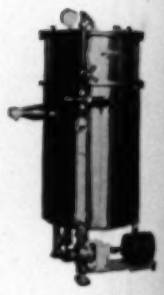
PFAUDLER EMULSIFIERS:

These stainless steel premixers (40, 100 and 250 gals.) are designed to emulsify such products as mayonnaise and salad dressings. The special forked beater-type stainless steel agitator produces a mixing action which chops and whips to bring about a homogenous mixture. Deep dish of bottom head is utilized to attain high speed, vigorous agitation. Vinegar and oil supply feed tanks can be attached to unit. Continuous production can be attained with complete Pfaudler assemblies.



PFAUDLER PERCOLATORS:

These new stainless steel percolators circulate menstruum through the extractant under pressure which speeds up extraction. Filtration is carried on simultaneously. Heater in the re-circulating line applies controlled temperature to circulating menstruum, resulting in faster extraction. Second and third extraction can be obtained thus providing maximum yield from each batch.



Use this convenient form for further details —

THE PFAUDLER CO., Dept. FT-8, Rochester 3, N. Y.

Please send me bulletins checked: Pfaudler Kettles ☐; Pfaudler Gravity Fillers ☐; Pfaudler Piston Fillers ☐; Pfaudler Emulsifiers ☐; Pfaudler Percolators ☐.

NAME_____

COMPANY_____

ADDRESS_____

CITY_____ ZONE_____ STATE_____

Pfaudler

THE PFAUDLER CO., ROCHESTER 3, N. Y.

ENGINEERS AND FABRICATORS OF FOOD PROCESSING EQUIPMENT

Glass-Lined Steel . . . Stainless Steels . . . Nickel . . . Inconel . . . Monel Metal

The Scientific Society and Technical Progress

Along with the remarkable growth of American science during the past century has come an increase in number of scientific societies. Few of us realize how swiftly that development has come. Since the turn of the century, the number of people who have published research has increased from about 4,000 to 20,000 in 1932 and since 1932 this rate of increase has probably continued. In 1927 the National Research Council reported 783 scientific and technical societies in the United States and Canada. In 1948 the number had increased to 1468—a 100% increase. Sometimes we are puzzled to decide just how we can divide time—not to mention money—among scientific organizations. In many we wish to participate as members. In others we wish to participate as subscribers to, and readers of, their publications and thus follow their progress.

The occasional, if not frequent, critical comments leveled against scientific organizations usually run in such directions as the following—The programs are dull, and attention and attendance at technical sessions all too often are not what they should be. Support of these societies and time required for attendance drain personal resources and require sacrifices. The coming of specialized societies, along with specialized science, has meant a necessity for membership in not one society, but several, because each makes a definite contribution to broad integrated progress, to which we can never afford to be wholly indifferent without appreciable loss to ourselves.

The situation is not so bad as it may frequently appear to be. Probably the best corrective lies in a modification in our thinking about the purposes and functions of scientific societies. Too often we ourselves, as members, forget that we *make* the scientific society. We too frequently expect to *get* something, forgetting that in a democratic organization no one *gets* anything unless someone *gives* something. If the organization is to amount to anything, many must give, and among contributions—financial, intellectual and administrative—the intellectual are those most basically necessary.

First I want to deal briefly with reasons why free, democratic technical organizations will continue to serve industry, science and the public, and then with methods that will improve the operations of these societies as they continue into the future. There is definite indication now that numbers of societies are not increasing. The more than 1400 societies I mentioned earlier include the large, well established organizations that have historic backgrounds and are potent factors in national policies, as well as smaller regional societies. Together they constitute a phase of American life and democracy whose power and value are much greater than is commonly realized.

The chief reason why technical societies must and will continue to function is the fact that science and technology have come to play one of the major roles in the production of the world's goods. We used to say (and still say, of course) that the three factors basically essential for production are land, capital and labor. Given those three, the enterprise can proceed. Nowadays, however, enterprising companies or individuals do not dare think of investment, building and operation unless they have called science to their aid. Even the best of technological investigation does not remove all risk, but it reduces risk and increases confidence and stability. Large existing companies regard their research and technological consultation as an essential prerequisite to changes and developments in production. Problems of *capitalization* and *labor* must actually wait on the decisions of the technical and scientific staff, and weakness or failure in the decisions of the technologists may spell failure and ruin in the ultimate venture.

The fundamental reasons for the association of scientists in organizations are, I believe, twofold. First there is one that we can conveniently call psychological. Feeling woefully inadequate as individuals, in the face of such large responsibilities, we seek the advice, support, and corrective guidance of fellow scientists. The time has long since passed when even the largest of our patrons—the very large corporations—could rely *wholly* on their own research organizations, although many have relied largely on their own research and have succeeded amazingly well. In industry we have come to realize, during the past half century, that the technical problems are too massive to be solved by individuals and small groups. We must have, as individuals or separate segments of an industry, that feeling of being a part of a national—and perhaps international—trend of growth and development.

Then, as a second reason for scientific associations, I would mention the need for competitive intellectual activity. The society with its forensic as well as printed media of expression, gives us the opportunity to contribute to the general progress. That reason is psychological, too, as everything is, in one sense, but I have in mind an industrial *modus operandi*—a method by which we maintain investment values in industry, and keep industry vigorous, alive, and productive. We accomplish that end as scientists and technologists—not as individuals wholly but as individuals working together in societies, where we compete, make our rules and estimate our success or failure by our contributions to general progress and progressive stabilization of the productive industries and to the general public that we serve.

The need for better organized technical societies will continue. Our basic resources are changing constantly. Our soils, crops, animals, minerals and basic science and our populations are undergoing continuous and recognizable changes. National and international trade changes constantly, and world politics "always changing" affect us directly—often more than we realize. The greater reason, then, to make our scientific associations more effective.

The future of our technical and scientific societies must be guarded carefully, because weakness or failure in their activities may contribute to regression or stalemating in our lives as individuals and as a nation. Even restlessness and impatience can be valuable capital, because they help us purge the nonessential things—the tiresome and expensive trivia. Realization that a scientific or technological society is an *essential instrument* in modern times is basic. Complete recognition of that is an absolute necessity. The better and the more numerous the *contributions* we make to our societies, the more effectively they will serve us as individuals, as parts of commercial enterprises, and as members of the general public. Our ability to concentrate on the factors that *really exist* in industry is the real measure of our success, because we live in and by means of, industry. And here I mean industry in the broad sense of the term, which includes vision, industriousness, efficiency, organization, production, and the personal gratification that comes from contribution to the progress of man.

H. C. DIEHL
President I. F. T., 1948-49

Notes and Letters

Rational Grading of Food Quality

A rating computed from quality ratings of various single properties as their harmonic mean gives definitely better correlation with "total" quality than their arithmetic mean.

A new mathematical technique is presented for the derivation of an overall quality score for food products from scores allotted to a number of individual properties. The method employs either the Geometric or Harmonic Mean, and evidence is adduced that the overall quality score so derived is more representative and more in accordance with direct judgment than a former method employing the arithmetic mean.

Plank has in a recent publication [a] given a survey of a rational method for quality grading of food products. The author of this paper has been using a grading method, which to a great extent coincides with the method recommended by Plank but on some points differs significantly from Plank's method. It is the opinion of the present author that his method gives a more correct interpretation of the actual "total quality" of the products. Our "quality scale" is based upon an evaluation of the quality expressed in words or corresponding numbers as follows:

Excellent	10
Very good	9
Good	7
Medium	5
Poor	3
Very poor	1
Unacceptable	0

According to the author's experience there is a marked tendency to subconciously try and make subdivisions in the quality scale closer than the actual reproducibility of the judges warrant, e.g. introducing decimals when the whole quality is 10 — 0. This would imply a "sensitivity" of perception definitely better than ± 10%. This might be true under certain rather exceptional conditions with extremely well trained judges, etc.

In general, however, the variations in "reproducibility" is likely to be not less than ± 10%. For this reason we have limited the number of descriptive terms of quality to seven. This seems to be the maximum of terms to be soundly used by un-trained "test-panels" of observers.

When the testing person describes the quality as being between good and very good there still are whole digits in reserve in the scale. More trained observers can of course be allowed to give their judgment directly in figures and also here the existence of whole digits between the digits allotted to the various descriptive terms seems to facilitate the judgment.

The "quality scale" mentioned above has, according to the author's experience, lent itself easily to subjective evaluations of quality of very widely varying types of commodities.

To obtain a "total" quality rating Plank recommends taking a weighted arithmetical mean of the rating of single properties, which are chosen to be independent of each other to the degree this is possible. As such properties for frozen food Plank has used

Taste (flavor)
Aroma (odor)
Consistency
Color
Form (appearance)

In grading canned foods the author has successfully used a very similar choice of properties:

Appearance (color and form)
Odor
Taste
Consistency

When computing the "total" quality rating the taste was "weighted" doubly against the other properties. This coincides completely with Plank's system. We found, however, a weakness in the method of expressing the "total" quality by computing the arithmetic mean. If for example the taste has been judged to be "very poor" = 1 and the other properties have all been given the rating 10, the total quality rating will be 6.2, which is definitely too good. This is a rather extreme combination of single qualities but not at all an impossible one. Compare a case when the taste has been impaired by reaction of the canned food with the metal of the container or when the color alone has been impaired.

The extra condition that the rating 0 for any single property automatically shall infer the total quality rating 0, can to some extent alleviate this inherent weakness in the system. When the single property, mentioned above, is judged as "very poor" but not "unacceptable" the total quality rating is still likely to be too good.

This is even more significant when appearance or one of the other singly weighted properties is very poor. A rating = 1 for appearance and 10 for the other properties gives a total rating = 8.2.

The system recommended by Plank does therefore not sufficiently take into account the impairment in "total quality" brought forth by some single property being "poor" or "very poor." This can be markedly improved by using a geometric or still better a harmonic mean of the single quality ratings to obtain the "total" quality rating. This means that the results will be identical with the arithmetic mean only when all the single quality ratings are identical.

In other cases the total rating will be lower than the rating obtained by taking the arithmetic mean. This

[a] Plank, R. P. A rational method for grading food quality. *Food Tech.* 2, 241 (1948).

is in accord with practical experience. The total quality rating will also always be zero when any single quality rating is zero.

The use of weighted ratings for the single properties will be much the same as in the system recommended by Plank.

The formulae for the geometric and harmonic means are given below using the same nomenclature as used by Plank.

$$\text{Geometric mean} = \sqrt[\Sigma m]{g_1^{m_1} \times g_2^{m_2} \times g_3^{m_3} \times \ldots}$$

$$\text{Harmonic mean} = \frac{\Sigma m}{\frac{m_1}{g_1} + \frac{m_2}{g_2} + \frac{m_3}{g_3} + \ldots}$$

$$\text{Arithmetic mean} = \frac{m_1 g_1 + m_2 g_2 + m_3 g_3 + \ldots}{\Sigma m}$$

Where: m_1, m_2, etc. are the weighting factors of the individual properties being graded.
g_1, g_2, etc. are the grades awarded to the individual properties.

The usefulness of this method of computation of "total" quality was controlled by several experiments carried out as follows:

Several trained as well as untrained persons were asked to judge several products according to the "scale," given above, and also to give a "general" rating designating what they would call the "total" quality of the product. The result was that for total quality ratings well above 6 the differences were slight between "total" quality ratings assessed directly by the judges and computed according to the formulae.

Where, however, the quality was poorer and especially when there was one single property which impaired the quality, there was definitely a better correlation between the "total" quality directly judged and the geometric and harmonic mean, than between the directly judged quality and the arithmetic mean.

The computation of these means is only slightly more complicated than the computations of the arithmetical mean. The improvement of the total quality rating does in the opinion of the present author well warrant this slight extra labour.

The differences between the three types of total quality ratings are illustrated below with three imaginary examples. Table 1 and Figure 1 illustrate a case with two single properties equally weighted. We start with both single ratings = 5 and make a series of new pairs, each time deducting one unit from the rating,[b] and adding one unit to the other.

TABLE 1

Single ratings a	b	Mean values: Arithmetical	Geometrical	Harmonical
5	5	5	5	5
4	6	5	4.9	4.8
3	7	5	4.6	4.2
2	8	5	4.0	3.2
1	9	5	3.0	1.8
0	10	0[b]	0	0

[b] By extra condition.

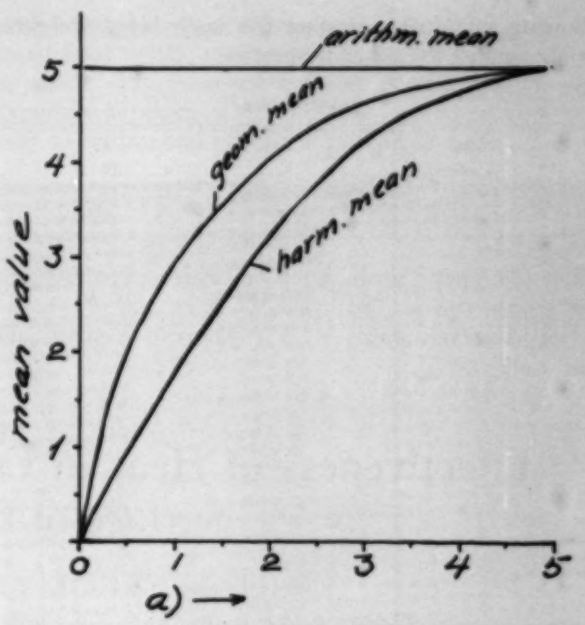


FIG. 1. Mean values where two properties are equally weighted.

In Figure 1 the single ratings a) have been taken as abscissae and the "means" as ordinates. Table 2 and Figure 2 illustrate a case with 4 properties equally weighted and where the three are constantly equal to 10 whereas the fourth gradually diminishes to zero.

In the third example we compare the results of computing the three different total quality ratings for the

TABLE 2

Single ratings a	b	c	d	Mean values: Arithmetical	Geometrical	Harmonical
10	10	10	10	10	10	10
9	10	10	10	9.8	9.7	9.7
7	10	10	10	9.3	9.1	9.1
5	10	10	10	8.8	8.4	8.0
3	10	10	10	8.3	7.4	6.4
1	10	10	10	7.8	5.6	3.1
0	10	10	10	0[c]	0	0

[c] By extra condition.

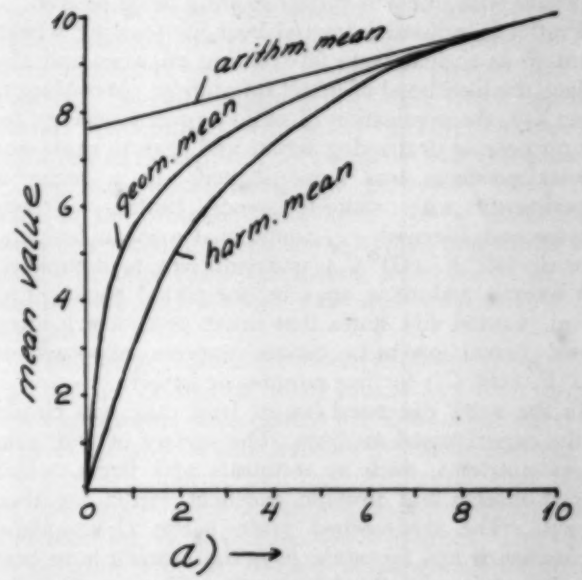


FIG. 2. Mean values where four properties are equally weighted.

following imaginary product the taste being weighted doubly against the other properties.

Quality rating	
Taste	1
Appearance	10
Odor	10
Consistency	10

The arithmetic mean is: 6.4: between medium and good.

The geometric mean is: 4.0: between medium and poor.

The harmonic mean is: 2.2: between poor and very poor.

It seems to the author that it is rather obvious that a product with a "very poor" taste can not be regarded as much better than poor and certainly not as above medium even if the other quality ratings are excellent.

A theoretical justification for the use of the harmonic mean might be found in the psycho-physiological fact that the various sense-excitations are interdependent.

F. JAKOBSEN
A/B Platmanufaktur,
Gothenburg, Sweden.

Effectiveness of Heat in Controlling Insects Infesting the Surface of Bakery Products

WILLARD J. GODKIN AND WILLIAM H. CATHCART
The Great Atlantic and Pacific Tea Company, National Bakery Division, New York 17, N. Y.

Experimental results are reported in which different types of heat radiation, such as infra-red, oven, and radio-frequency, were used for the purpose of trying to destroy eggs of grain and cereal infesting insects. Infra-red and oven radiation were found to be most effective for this purpose. Emphasis is placed upon infra-red radiation as an effective and practical means for surface sterilization of a long shelf-life bakery product such as fruit cake.

Introduction

Heat can be effectively utilized in killing all stages of insects of the type which infest grain, cereals, dried fruits, and nuts. With respect to bakery products, interest was centered upon a type of heat treatment of the wrapped or finished packaged product which would result in surface sterilization, in so far as insect eggs were concerned, without altering the food product or damaging the packaging material. Consequently the method necessarily would have to be one of short-time exposure with uniform surface heating being desired.

Pratt *(5)* utilized infra-red heat for toasting wheat-germ so as to inactivate fat-splitting enzymes and also reduce the likelihood of insect infestation. According to Kinn *(4)*, the application of radio-frequency energy for the purpose of destroying larvae and eggs in grain and similar products was demonstrated. In a series of experiments with radio-frequency heating, Brown, Hoyler and Bierwith *(2)* found that a mean temperature of 140° F. (60° C.) was sufficient to completely kill weevils and their eggs in one-pound packages of cereal. Cotton *(3)* states that insect pests which infest milled cereal products cannot survive exposure to 140° F. (60° C.) for five minutes or longer.

In the work discussed below, fruit cake was chosen as the experimental medium. The surface of fruit cake offers nutrients, such as nutmeats and fruits, which attract insects and provide excellent media for their growth. The saw-toothed grain beetle *Oryzaephilus surinamensis* and fig moth, *Ephestia cautella* have been found as contaminants of fruit cake. These and similar insects like the confused flour beetle, *Tribolium confusum* may deposit their eggs, which are hardly dis-

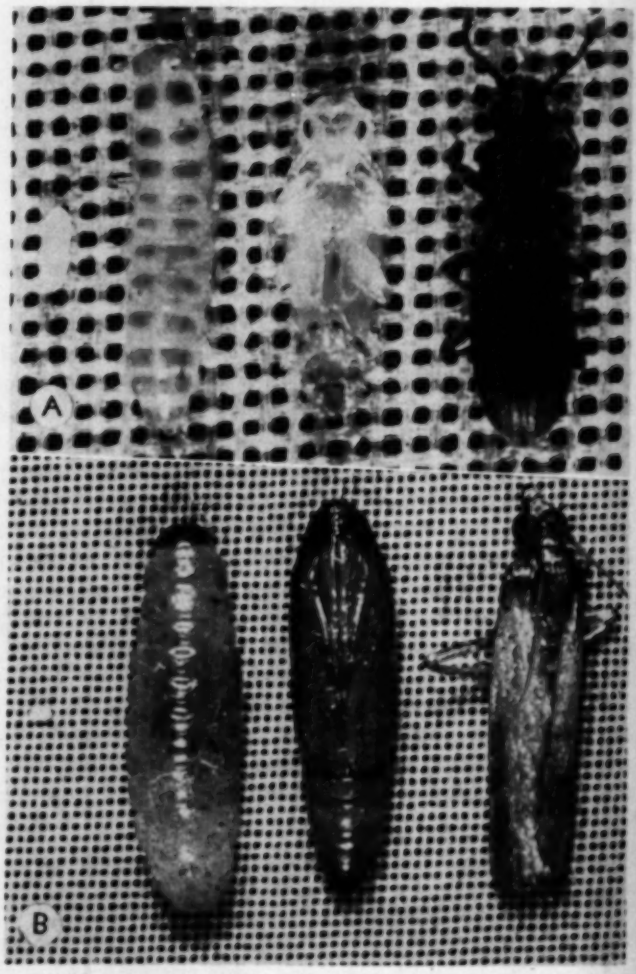


FIG. 1. Life stages of grain and cereal infesting insects on 10xx cloth. A. Egg, larva, pupa, and adult of saw-toothed grain beetle, *Oryzaephilus surinamensis*. (Mag. about × 14). B. Egg, larva, pupa, and adult of fig moth, *Ephestia cautella*. (Mag. about X 5.5.)

cernible to the unaided eye, on the exposed product's surface before the wrapping operation has taken place. Sometime later, after the cakes have been wrapped and distributed, the eggs hatch. In Figure 1 are illustrated the four stages in the life cycle of the saw-toothed grain beetle and the fig moth. Some idea of the small size of the eggs from these insects can be gained when considering the magnification of the illustrations and the relation in size of the eggs to the other life stages of the insects. Figure 2 shows the extent of insect damage to

FIG. 2. Damage to surface of fruit cake caused by saw-toothed grain beetle, *Oryzaephilus surinamensis*. Arrows indicate some of the points of damage.

the surface of a fruit cake which had been artificially contaminated with eggs from the saw-toothed grain beetle. The larvae of these insects have ravenous appetites and while growing to a noticeable size consume food and deposit a large amount of coarse frass.

Experimental Methods

Three sources of heat were used: 1. Infra-red heat provided from a battery of 31-250 watt G. E. type infra-red lamps set up to form a tunnel radiating heat from the top, bottom, and sides; 2. Oven heat supplied by a laboratory size electric fired despatch oven, and; 3. Radio-frequency heat obtained from a 2 kilowatt radio-frequency unit operating at a frequency of 25 megacycles. When using infra-red heat, the temperature of the area where the test sample was placed was recorded by using thermocouples and a potentiometer. The infra-red heated exposure area was allowed to reach a temperature of approximately 550° F. (288° C.) before subjecting the test samples for varying periods of exposure. Where oven heat was used, the test samples were placed in a temperature controlled oven and held there for varying intervals at a temperature of approximately 450° F. (232° C.). In the case of radio-frequency heat, the temperature of the surface of the test sample was recorded by placing a metal stem Weston thermometer underneath the cellophane wrapper and across the surface of the fruit cake test samples to a midway point. Glass Petri dishes of approximately ¾-inch depth separated the test samples from contact with either electrode and served to prevent burning from the "arcing" which occurred when the glass liners were not present. The two copper electrode plates were set 4½-5 inches apart in an arrangement similar to that used in the electronic experiments reported by Bartholomew, Harris, and Sussex *(1)*.

Samples of fruit cake were wrapped with cellophane after being surface contaminated with eggs of the confused flour beetle, the saw-toothed grain beetle, and the fig moth. The confused flour beetle was used in these experiments along with the other insects because it is easy to culture and prolific in producing eggs. Figure 3

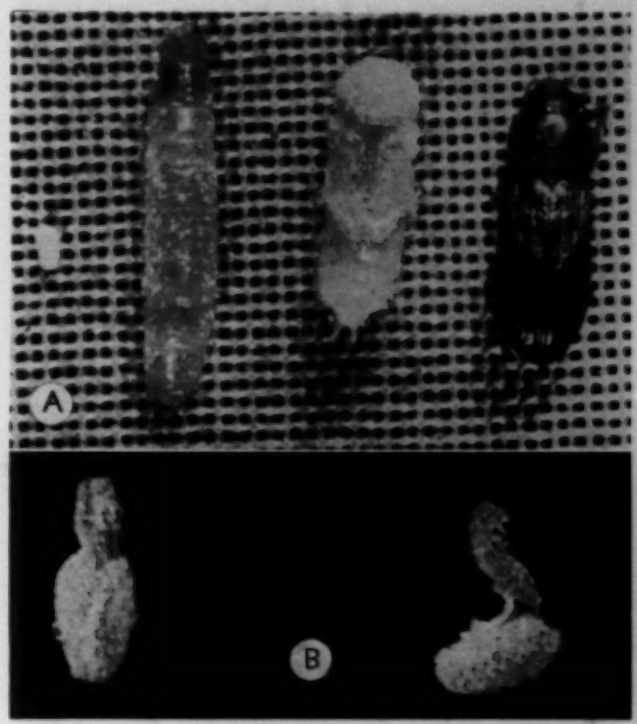


FIG. 3. Life stages of confused flour beetle, *Tribolium confusum* on 10xx cloth. A. Egg, larva, pupa, and adult. (Mag. about × 11.) B. Hatching of eggs. Larva at the right is 10 minutes old. (Mag. about × 48.)

shows the life cycle of the confused flour beetle and larvae of the same insect species emerging from eggs. After exposing the infested samples of fruit cakes to the different types of heat for certain time periods and temperatures, the test samples were incubated at room temperature, 75-80° F. (23-27° C.), and examined periodically during a holding period of one month to see if the insect eggs had hatched. Test samples of fruit cake containing insect eggs but not subjected to heat were incubated with the heated samples to serve as controls. Several samples of fruit cake which had been surface contaminated with insect eggs were exposed to infra-red radiation prior to wrapping with cellophane.

The majority of tests were performed using fruit cake as the processed food item. A few experiments were conducted in which larvae, pupae, and adults were used. In some cases the insects were placed in Petri dishes with and without food and subjected to heat treatment.

Although germicidal ultraviolet radiation is not recommended for destroying small insects and their eggs, a few experiments were carried out to see what effect this type of radiation would have on the larvae and eggs of the confused flour beetle. Eggs and larvae were placed in open glass Petri dishes and exposed to ultraviolet radiation for ½, 1, 2, 3, 4, and 5 minutes. The source of radiation was two 30-inch Westinghouse Sterilamps spaced 6 inches apart and 13 inches above the dishes.

Results and Discussion

Tables 1 to 6 list the sources of heat, temperature, conditions under which insects were exposed, length of exposure, and effectiveness of treatment.

TABLE 1

Lethal Effect of Infra-Red Heat When Applied to Eggs and Adults of Confused Flour Beetle, Tribolium confusum.

Exposure Temp. in ° F.	Stage of Insect and Condition Under Which Exposed	Exposure Interval in Seconds	Effectiveness of Treatment *
545	Eggs placed on black paper liner on top of fruit cake. Cake wrapped with cellophane.	2	+
545	Same	4	+
545	Same	6	+
545	Same	8	+
Control	Same	0	−
550	Eggs placed in open Petri dishes.	2	−
550	Same	4	−
550	Same	6	−
550	Same	8	−
Control	Same	0	−
540	Eggs placed on nutmeats in open Petri dishes.	15	+
540	Same	30	+
540	Same	60	+
540	Same	120	+
540	Same	180	+
Control	Same	0	−
540	Eggs placed at random on cake's surface. Heated before wrapping with cellophane.	10	+
540	Same	20	+
540	Same	30	+
Control	Same	0	−
540	Adult insects placed in open Petri dishes.	1	−
540	Same	2	−
540	Same	3	+
540	Same	5	+

* + = Kill; − = Ineffective.

TABLE 2

Lethal Effect of Infra-Red Heat When Applied to Eggs of Saw-Toothed Grain Beetle, Oryzaephilus surinamensis.

Exposure Temp. in ° F.	Conditions Under Which Eggs Were Exposed	Exposure Interval in Seconds	Effectiveness of Treatment *
560	Eggs placed on nutmeats on top of fruit cake. Cake wrapped with cellophane.	1	−
560	Same	2	−
560	Same	4	−
560	Same	9	−
560	Same	15	+
560	Same	30	+
560	Same	45	+
560	Same	60	+
560	Same	75	+
Control	Same	0	−
540	Eggs placed on nutmeats in open Petri dishes.	10	+
540	Same	15	+
540	Same	20	+
540	Same	30	+
540	Same	40	+
540	Same	50	+
540	Same	60	+
Control	Same	0	−
540	Eggs placed at random on cake's surface. Cake wrapped with cellophane.	15	+
540	Same	30	+
540	Same	45	+
540	Same	60	+
540	Same	90	+
Control	Same	0	−
540	Eggs placed at random on cake's surface. Heated before wrapping with cellophane.	10	+
540	Same	20	+
540	Same	30	+
Control	Same	0	−

* + = Kill; − = Ineffective.

TABLE 3

Lethal Effect of Infra-Red Heat When Applied to Eggs of Fig Moth, Ephestia cautella.

Exposure Temp. in ° F.	Conditions Under Which Eggs Were Exposed	Exposure Interval in Seconds	Effectiveness of Treatment *
530	Eggs placed at random on cake's surface. Cake wrapped with cellophane.	15	+
530	Same	30	+
530	Same	45	+
530	Same	60	+
530	Same	75	+
Control	Same	0	−

* + = Kill; − = Ineffective.

TABLE 4

Lethal Effect of Oven Heat When Applied to Eggs of Confused Flour Beetle, Tribolium confusum.

Oven Temp. in ° F.	Conditions Under Which Eggs Were Exposed	Exposure Interval in Minutes	Effectiveness of Treatment *
430	Eggs placed on black paper liner in Petri dish.	½	+
430	Same	1	+
430	Same	3	+
430	Same	5	+
Control	Same	0	−
450	Eggs placed on nutmeats on top of fruit cake wrapped with cellophane.	½	+
450	Same	1	+
450	Same	3	+
450	Same	5	+
Control	Same	0	−

* + = Kill; − = Ineffective.

TABLE 5

Effect of Radio-Frequency Heat on Treating Fruit Cake Samples Artificially Contaminated with Insects.

Species and Stage of Development	Exposure Interval in Minutes	Surface Temperature in ° F. at End of Exposure Period	Effectiveness of Treatment ***
Saw-toothed grain beetle eggs	1	114	−
Same	1⅛	100	−
Same	3½	142	+
Same	1	140**	−
Same (Control)	0	.....	−
Saw-toothed grain beetle larvae	1⅛	142**	−
Confused flour beetle eggs	2	100	−
Same	2½	124	−
Same	3¼	140	+
Same	1	180*	−
Same (Control)	0	.....	−
Confused flour beetle pupae	4	144	+
Same (Control)	0	.....	−
Large larvae and adults of confused flour beetle	4½	150	+

* Internal.

** Temperature recorded was spotty and did not represent the whole surface.

*** + = Kill; − = Ineffective..

Heat obtained from infra-red, oven, or radio-frequency sources was effective in killing all stages of insect life when adequate time was allowed for the cake's surface to reach a temperature of 140° F. (60° C.) or higher.

Where infra-red heat was utilized insect eggs which had been placed on nutmeats or at random on the surface of the fruit cakes were killed in 10 to 15 seconds when exposed to a temperature of approximately 550° F. (288° C.) without injury to the food product or the

TABLE 6

Effect of Germicidal Ultraviolet Radiation on Eggs and Larvae of the Confused Flour Beetle, Tribolium confusum.

Stage of Insect	Condition of Exposure	Irradiation Time in Minutes	Effectiveness of Treatment *
Eggs	Eggs placed in open Petri dishes.	½	—
Eggs	Same	1	—
Eggs	Same	2	—
Eggs	Same	3	—
Eggs	Same	4	—
Eggs	Same	5	—
Eggs	Same	Not exposed	—
10 day-old larvae	Larvae placed in open Petri dishes.	½	—
Same	Same	1	—
Same	Same	2	—
Same	Same	3	—
Same	Same	4	—
Same	Same	5	—
Same	Same	Not exposed	—

* — = Ineffective.

cellophane packaging material. Some experimental work not heretofore mentioned in this paper showed that it took approximately 30 seconds for the cake's surface to heat to 200° F. (93° C.) when placed in an infra-red heating area of 500° F. (260° C.). As shown in Table 1, the supporting medium influenced the rate at which insect eggs were killed by infra-red heat. The results obtained also indicate that the reddish-brown confused adult flour beetles probably absorbed the infra-red heat rays much faster than the lighter colored eggs of the same species. The killing effect of infra-red radiation was about the same whether or not the exposure took place before or after the wrapping operation. Exposures up to 1 minute did not damage the cellophane wrapping.

Although fewer experiments were conducted with oven heat, its effect was comparable to that of infra-red heat. Insect eggs which had been placed on the nutmeats on top of cellophane wrapped fruit cake test samples were killed in 30 seconds when the oven temperature was held at 450° F. (232° C.) (see Table 4). The infra-red method, however, in addition to being more readily installed in a production line, has a greater practical significance because the exposure area can be brought up to the desired temperature in less time than an oven of conventional design.

Radio-frequency heat, while effective in killing all stages of insects used, was not suitable for the type of product employed in the experiments. Due to the heterogenous composition of fruit cake, heating was uneven. It was necessary to heat the cake samples for 3¼ to 4 minutes in order to assure a surface temperature of 140° F. (60° C.) or higher. Although internal portions of the fruit cake heated rapidly by radio-frequency heat, the surface heating lagged considerably. Some faulty or spotty surface temperatures were recorded which did not represent the surface temperature as a whole (see Table 5). All life stages of the insects were killed when the surface temperature showed 140°-150° F. (60-66° C.) and a heating time interval of 3¼ to 4 minutes. Some condensation of moisture driven from the cake was noticed on the inner surface of the cellophane wrapper on those samples heated from 3¼ to 4 minutes. The condensed moisture was reabsorbed throughout the cake sample within a few hours.

Germicidal ultraviolet radiation had no effect on the larvae and eggs of the confused flour beetle (see Table 6). An irradiation time beyond 5 minutes was not attempted since such a long interval seemed impractical.

Conclusions

Infra-red heat offers a rapid and effective means of eliminating surface infestation of all stages of stored product insects in finished packaged products such as fruit cakes or other similar items.

Using an infra-red exposure temperature of approximately 500° F. (260° C.), it is possible to heat the surface of a finished packaged product like fruit cake to 140-150° F. (60-66° C.) within 20 seconds. This short interval of treatment is sufficient to kill any incipient insect infestation present without altering the food product or damaging the cellophane packaging material.

Comparable results may be obtained with heat supplied from an oven; however, it would be necessary to build a specially constructed oven which probably would not have as much flexibility as the infra-red setup.

For finished products containing a non-uniform mixture of baked ingredients, such as are present in fruit cake, radio-frequency heating does not offer a practical method for uniform surface sterilization.

Germicidal ultraviolet radiation up to 5 minutes exposure had no effect on the eggs and larvae of the confused flour beetle.

LITERATURE CITED

1. Bartholomew, J. W., Harris, R. G., and Sussex, F. Electronic preservation of Boston brown bread. *Food Tech.* 2, 91-94 (1948).
2. Brown, G. H., Hoyler, C. N., and Bierwirth, B. A. Theory and application of radio-frequency heating. D. Van Nostrand Co., Inc., New York (1947).
3. Cotton, R. T. Insect pests of stored grain and grain products. Burgess Publishing Co., Minneapolis, Minn. (1941).
4. Kinn, T. P. Basic theory and limitations of high frequency heating equipment. *Food Tech.* 2, 161-173 (1947).
5. Pratt, Jr., D. B. Infra-red toasting unit speeds wheat-germ processing. *Food Ind.* 20, 86-88 (1948).

Rapid Determination of Percent Inversion in Inverted Sucrose Syrups[a]

RICHARD N. PRINCE

Technical Department, California and Hawaiian Sugar Refining Corp., Ltd., Crockett, California

A method is described for determining the inversion in inverted sucrose syrups, applicable to control work where some precision can be sacrificed for speedy results. Percent inversion is obtained graphically from observed percent solids and polarization of inverted syrups.

During recent years there has been an ever increasing interest in liquid sugars, and since many of these are inverted syrups containing anywhere from 10 to 50% or more invert sugar, need has arisen for rapid means of determining the percent inversion in these mixtures. The term inversion as used herein refers specifically to the hydrolysis of sucrose and invert sugar refers to a mixture of equal parts of dextrose and levulose.

The determination of invert sugar has received its full share of attention from analytical chemists over the years as reference to any standard work on sugar analysis clearly demonstrates. Primarily, however, the usual methods employed resolve to a determination of the amount of copper reduced by the sugars, such as the Munson and Walker Unified method or the Lane and Eynon Method. Both are recognized by the Association of Official Agricultural Chemists.

Some methods have exploited the optical activity of sugar solutions. Ostwald investigated the optical methods in the early '80's and Ost *(2)* did additional work in 1891. More recently Vosburgh *(3)* added considerable to our knowledge in 1921 in his study of the kinetics of sucrose hydrolysis. Optical methods are not generally used for reducing sugars, however, due to the many difficulties attendant with these methods.

Optical methods, of course, depend upon the fact that sugar solutions, among other things, rotate the plane of polarized light, and the angle of the rotation can be measured in a polarimeter. The power to rotate the plane of polarization varies with different sugars. Some sugars, like sucrose and dextrose, rotate to the right, and others, like levulose, rotate to the left. It might be well to note that in a polarimeter adapted to saccharimetric work pure sucrose at a predetermined concentration polarizes 100°. In this same instrument invert sugar, composed of equal parts of dextrose and levulose, polarizes —31° *(1)*.

The method about to be described for the determination of percent inversion is an adaptation of the polariscopic method. Vosburgh, using mixtures of sucrose, dextrose, and levulose in concentrations up to 20% solids determined that the percent inversion could be calculated by means of the following equation:

$$\text{Percent inversion} = 100\,\frac{\text{As} - \text{A}}{\text{As} - \text{Ai}}$$

where As is the rotation of the pure sucrose, A is the rotation of the mixture and Ai is the rotation of the pure invert sugar for each concentration. This work has been verified in our laboratory, and the same relationship has been found at higher concentrations of sugar solids. From this equation it develops that regardless of concentration, inverted sucrose solutions have one common point, namely, zero polarization at 76.4% inversion, using the values of 100° for sucrose and —31° for invert.

Before describing this adaptation of the polariscopic method of determining the percentage of inversion, it should be well understood that elaborate procedures are required for precise work. In the present case, however, the method is designed for rapid control work and for use by personnel untrained in analytical procedures. At a small sacrifice in precision these objectives have been met. Using this method it is possible for operating employees to determine percent inversion with an error not greater than 2 or 3 percent in an elapsed time of about 10 minutes. Also, before proceeding further, it is well to point out again that the method is restricted to mixtures of sucrose and invert sugar.

As previously noted, sucrose solutions, regardless of density, all show zero polarizations when the sucrose is 76.4% inverted. This lends itself to rapid graphic interpretation. Plotting percent inversion as ordinates on a scale from 0 to 100%, and polarization as abscissae on a scale running from 100° to —30°, two points are located for a syrup containing any given concentration of sugar solids, namely, the polarization of sucrose for the given concentration, and the common point of 76.4% inversion. By connecting these two points with a straight line the relationship between polarization and percent inversion can immediately be ascertained for that particular concentration of solids. The point of intersection vertically above a particular polarization corresponds to the percent inversion which intersects the line horizontally at that point.

Illustrating the foregoing, suppose that it is desired to know the percent inversion of a sucrose syrup, containing 75% solids, which polarized —4° after inversion. First, on a piece of rectangular coordinate paper the proper scales are plotted (Figure 1), namely percent inversion from 0 to 100 and polarization from 100° to —30°. Second, the common point, zero polarization corresponding to 76.4% inversion is located. Third, the point of sucrose polarization at zero inversion (i.e., 75°) is located and this point connected with the previously located common point. Then, the point of vertical intersection corresponding to —4° polarization, projected horizontally, indicates 81% inversion.

In the foregoing, it will have been noted that the percent solids of the initial sucrose solution and the

[a] Presented before the Northern California Section of the Institute of Food Technologists, at their December 2, 1948 meeting, Albany, California.

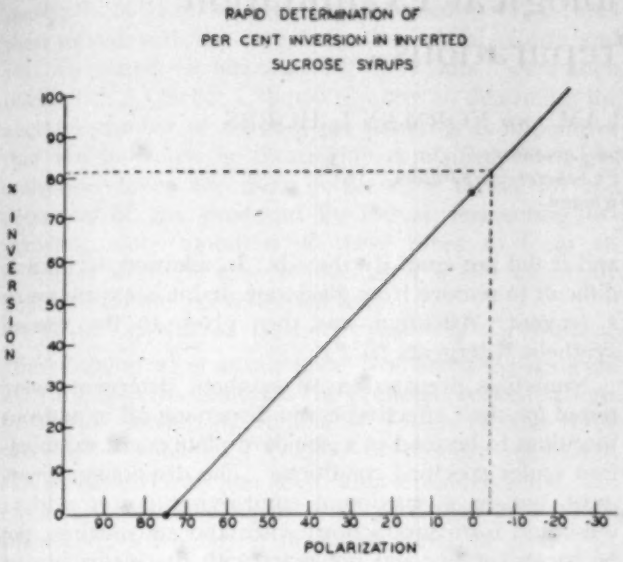


FIG. 1.

polarization of the initial solution are identical. In this method it is likewise assumed that the percent solids of an inverted syrup corresponds to the original percent solids of the sucrose syrup. This assumption is sufficiently accurate for most control work even though the inverted solids are about 5% greater than the original sucrose solids. Or if required, the amount of invert can be estimated on this basis and the 5% correction applied in order to obtain a somewhat more precise percent original sucrose solids. Thus, it is necessary only to determine the percent solids and the polarization of the inverted syrup in order to determine the percent inversion.

Without going into detail regarding technique, the percent solids is best determined by means of a refractometer; and polarization by using a normal weight for sucrose (26 grams), using usual sugar analysis methods. One additional item should be mentioned, however, and this is a means for overcoming the effects of mutarotation. Mutarotation, of course, is the change in rotation which takes place while the inverted sugars are reaching equilibrium and is due to the existence of more than one type of each of the reducing sugars present.

In early work on polariscopic methods of invert determination, mutarotation was allowed to run its natural course. Polariscope readings were taken some hours after solutions were made up. As is known, however, the change in rotation occurs almost instantaneously in alkaline solution. Therefore, judicious addition of sodium hydroxide to the cooled syrup, followed by prompt neutralization with acetic acid, completes the mutarotation in a few seconds so that the polarization of the sugar solution can be read immediately.

Further simplification in so far as control work is concerned is possible if operating procedures are well standardized. For example, if the sucrose solution being inverted is maintained at a standard density the percent solids and initial sucrose polarization are fixed. With these points fixed, it is then possible to overcome the necessity for weighing out a normal weight of syrup. This is done by using undiluted syrup in a polarization tube whose length is determined by the percent solids in the undiluted syrup. This length can be calculated quite readily. For example, in regular analytical work a normal weight of syrup is made up to 100 ml. with water and the resultant solution read in a 200 mm. polariscope tube. Requisite tube length, therefore, is

$$200 \times \frac{\text{normal weight of invert syrup per 100 ml.}}{\text{weight of invert syrup per 100 ml.}}$$

As an illustration, 100 ml. of a sucrose syrup containing 75.5% solids weighs 138.5 grams. Substituted in the foregoing, this calculates to 37.5 mm. for the required tube length. This particular tube length has been used quite satisfactorily in plant control work.

Also, if operating conditions are standardized and the sucrose inversion is proceeding at temperatures as high as 60-70° C., as is usually the case, mutarotation is no longer a problem. Equilibrium is reached rapidly at the higher temperatures. Furthermore, using the undiluted syrup, no additional mutarotation is introduced by sample dilution.

For control work then, it becomes possible to make a rapid invert determination as follows:

1. Take a sample of the inverting syrup and cool to approximately room temperature.
2. Place the cooled syrup in a specially prepared polariscope tube of predetermined length.
3. Read the polarization and convert the reading to percent inversion by means of an appropriate graph or table.

In conclusion, a method for the rapid determination of percent inversion in inverted sucrose syrups has been devised for control use. By means of it an operator, untrained in analytical procedure, can determine the percent inversion within 2 or 3% in about 10 minutes elapsed time. This is a great advantage over more precise methods which require both trained analytical personnel and considerably more time for completion. The method which was developed in collaboration with other members of the Technical Department, has been used to good advantage for several years in the C and H refinery.

LITERATURE REFERENCES

1. BROWNE, C. A., AND ZERBAN, F. W. Physical and Chemical Methods of Sugar Analysis, p. 302.
2. OST, BER., 24, 1639.
3. VOSBURGH, W. C. The optical rotation of mixtures of sucrose, glucose, and fructose. *J. Am. Chem. Soc.*, 43, 219 (1921).

A Method for the Bacteriological Examination of Edible Fat Preparations[a]

BERYL F. CAPPS, MARY K. WOLLAM AND NORMAN L. HOBBS

Microbiological Control Laboratory,
Gelatin Products Division, R. P. Scherer Corporation,
Detroit 13, Michigan

Various diluents for emulsifying edible fats and oils for bacteriological examinations are considered. A mixture of G-2800 three per cent by volume and Tween 80 two per cent by volume proved to be the most suitable.

Viable bacteria may be recovered from various types of oils including cutting compounds *(10)*, lubricating oils from oil wells and oil soaked soils *(14, 16, 13)*, fish oils *(9, 4)*, butter *(15, 5)*, and many others. During the bacteriological examination of chicken fat, fish liver oils and other edible oils and fats, the problem of developing a satisfactory method for such examinations has presented itself.

Initial experiments following standard plate count procedure *(1, 2, 8)* demonstrated that growth encountered as a contaminant in the oil appears as dense clusters of colonies around the oil droplets which are formed on the surface of the agar. These dense clusters make accurate colony counting difficult. Preparation of the inoculum by dispersal of the oil in sterile milk and cream was unsatisfactory *(3)*. Previous investigations had shown that lecithin withstands autoclaving and is not bacteriostatic *(12)*. Lecithin was used in concentrations of from one percent to five percent in aqueous solution, but it was difficult to disperse in water *(11)*, and it did not emulsify the oils. In addition, lecithin is difficult to remove from glassware and it is expensive as a reagent. Attention was then given to the use of synthetic detergents *(6, 7)*.

Numerous preparations of synthetic detergents were tested for their effectiveness in dispersing oil in aqueous inoculum to be used in a standard plate count examination under specified conditions. The dispersing agents must possess a maximum emulsifying power with a minimum foam production; withstand autoclaving; not be bacteriostatic; and not react with the media in any manner that would interfere with the nutrition, differential growth and evaluation of the bacterial flora. A sterile mixture of vegetable shortening and chicken fat held at 37° C. was experimentally contaminated with a 24 hour culture of strain 6538 FDA 209 of *Staphylococcus aureus* grown in a tryptose dextrose phosphate broth. This contaminated oil was used as inoculum for the detergent experiments. The detergents were prepared in specified concentrations (see Table 1) in aqueous solution and were autoclaved in 10 ml quantities in standard culture tubes with cotton plugs. For the tests 1 ml of the oil inoculum was added to each of the tubes containing the sterile detergent. After delivery of the fat into the tube, the same pipette was used to mix the inoculum to form an emulsion. As soon as the emulsion was formed, the pipette was used to transfer 1 ml aliquots to plates and tube media. Approxi-

[a] Presented before the Third Session, 76th Annual Meeting of the American Public Health Association, Boston, Massachusetts, November 10, 1948.

TABLE 1

Comparative Effects of Detergents on Emulsification, Withstanding Autoclaving, Reaction with Media and Effect Upon Growth of Staphylococcus aureus

Name of Detergent	Effects of Autoclaving	Emulsion of Oil in Inoculum Tube	Emulsion of Inoculum in Agar When Solidified	Reaction to Dyes in Media	Average Colony Counts on Plates
Hifoam [a] *	Separated and congealed	Poor, foam formation, plugs wet	Good dispersion	No change	None
Monoethanolamine†	None	No emulsion	No emulsion	No change	None
Polyethylene Glycol *(8)*†	None	No emulsion	No emulsion	No change	One cluster in oil droplet
Santomerse [b] *	None	Poor, foam formation	No emulsion	Darkens EMB Agar	None
Sulfonated Castor Oil ‡	Creamy	Fair emulsion	No emulsion	Precipitates dyes in EMB	None
Tergitol Wetting Agent-4 [c] †	Cloudy	Fair emulsion, foam formation	No emulsion	No change	None
Triton X-45 [d] †	Separates	Fair emulsion, foam formation	No emulsion	No change	None
Triton X-100 [d] †	None	Poor, foam formation	Good emulsion	No change	None
Mixture: ‡ Triton X-45 2% Triton X-100 3%	Separates	Poor, foam formation	Partial emulsion	No change	None
Mixture. *(14)* *(9)* ‡ Tween 80 * 2% G-2800 * 3%	Cloudy	Good emulsion	Excellent emulsion	No change	160 colonies

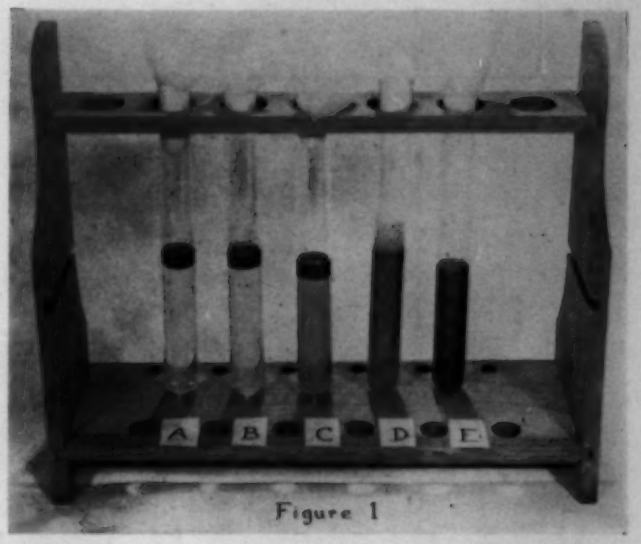
* — 3% by Wt. † — 3% by Vol. ‡ — 5% by Vol.

[a] Emulsol Corp., Chicago, Illinois. [b] Monsanto Chemical Corp., St. Louis, Missouri. [c] Carbide and Carbon Chemical Corp., N. Y., N. Y. [d] Rohm and Haas, Philadelphia, Pa. [e] Atlas Powder Co., Wilmington, Del.

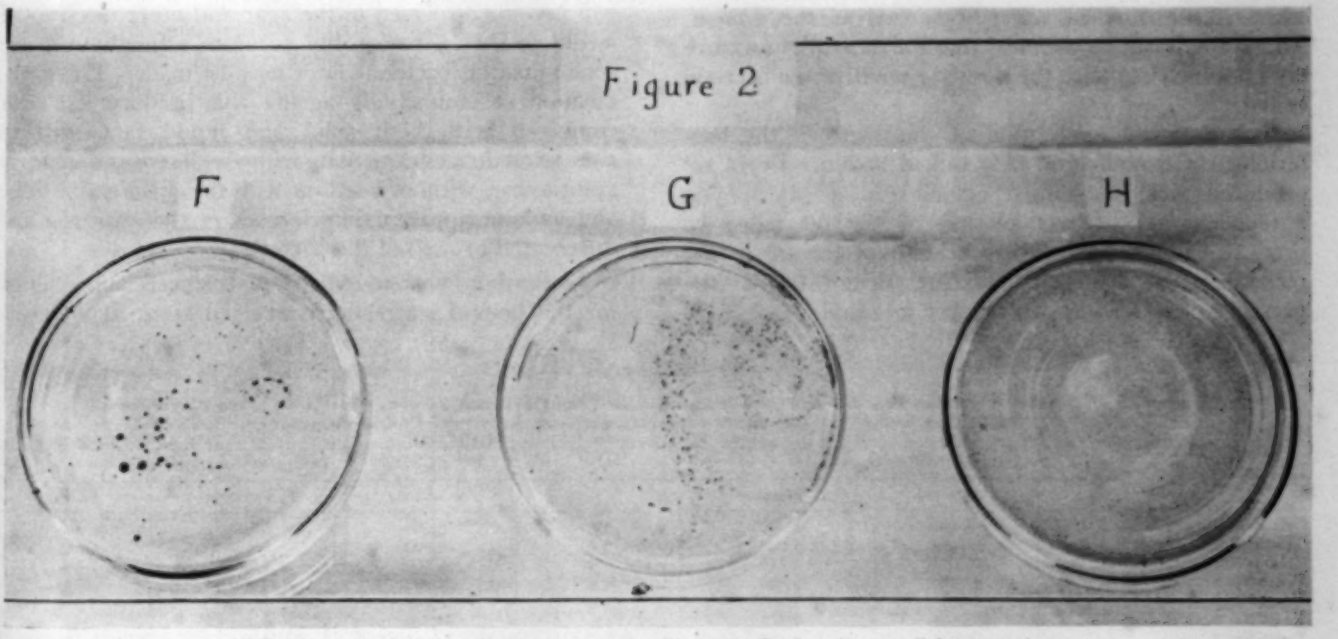
mately 12 to 15 ml of melted agar, cooled to 45° C., was then mixed with the inoculum, allowed to solidify and was incubated 48 hours at 37° C. Counts were then made with a Quebec Colonoy Counter to determine the average number of colonies per plate. It is imperative that the inoculum be thoroughly emulsified when gas collection tubes are used in the tube media for the detection of gas produced by lactose fermenting organisms, since agitation of these tubes to form an emulsion after the tube is inoculated would admit air bubbles into the gas collection tube.

Of the detergents tested (Table 1), the Tweens offered the greatest advantages. Numerous experiments with the Tweens indicated the optimum concentrations to be two percent by volume of Tween 80 and three percent by volume of G-2800 to produce maximum emulsification with the least unfavorable results. An efficient emulsifying agent is of particular importance when cool, solidified fat mixtures are to be tested, as exemplified by the chicken fat capsules. Less than two percent concentration of Tween 80 alone produced very little emulsification, from two percent to five percent Tween 80 alone produced an acceptable emulsion but when combined with G-2800 in the above recommended proportions the most stable emulsion was produced. When G-2800 was used as the sole emulsifying agent, the inoculum became quite milky and left an opaqueness to the agar which interfered considerably with colony counting, whereas in the recommended combination, this difficulty is not encountered.

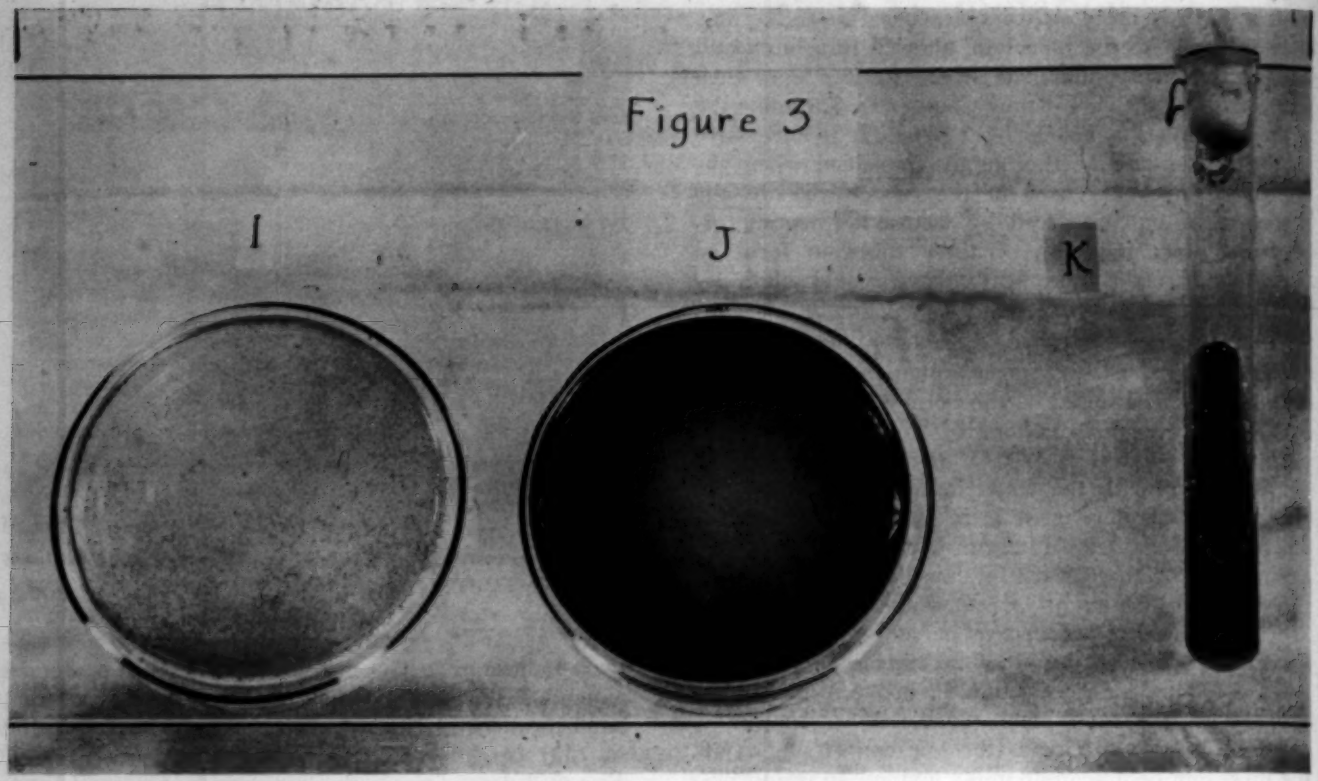
As an illustration of the effectiveness of the formula described a quantity of corn oil containing a reddish yellow dye was mixed with various diluents and detergents and then inoculated into different media. Figure 1 demonstrates the effects of the oil inoculum in (A) distilled water, (B) three percent polyethylene glycol, (C) five percent Tween 80, (D) three percent Triton X-100 and (E) five percent mixture of Tween 80 (two percent) and G-2800 (three percent). In (A) and (B) there is little or no dispersion. In (C) there is a small amount of intermixing while in (D) and (E) excellent emulsification is achieved. However, the Triton X-100 in (D) produces too much foam to be satisfactory. Figure 2 demonstrates the appearance of several types of inoculum in the agar plates. In (F) only water was employed as a diluent. In (G) five percent Tween 80 was used while in (H), the five percent mixture of Tween 80 (two percent) and G-2800 (three percent) was used. In Figure 3, the recommended five percent mixture of Tween 80 and G-2800 was used to disperse the colored oil in three typical media often employed in bacteriological examination. Plate (I) represents the dispersion in Tryptone Glucose Extract Agar for colony counts. Plate (J) represents the dispersion in Eosin Methylene Blue Agar for coliform counts while



Effectiveness of various detergents on the dispersal of colored corn oil in water.



Effectiveness of various detergents on the dispersal of colored corn oil in agar plates.



The recommended five per cent mixture of Tween 80 and G-2800 used to disperse colored corn oil in three typical media employed in bacteriological examinations.

tube (K) represents the dispersion in a Brilliant Green Bile Broth with gas fermentation tube.

In addition to testing the Tween mixture with *Staphylococcus aureus* for bacteriostasis, the aqueous Tween mixture was used to dilute samples of powdered brewer's yeast and ground pharmaceutical gelatin which were experimentally contaminated with *Staphylococcus aureus* and *Proteus morganii* (Table 2). The averages of the plate counts using the detergent mixture agreed within experimental error with the results obtained when sterile distilled water was used as the diluent. Therefore, it can be assumed that the detergent mixture does not interfere with the normal growth of the bacteria tested.

In a practical application of this method, the bacteriological examination of a rancid halibut viscera oil produced well distributed colonies of a saprophytic *Mycobacterium*. Direct plating of the oil failed to produce growth while emulsification of the oil in the recommended detergent mixture demonstrated the presence of 300,000 organisms per ml of oil.

Summary

The use of an aqueous mixture of synthetic detergents composed of two percent by volume Tween 80 (a mono-oleate of sorbitan polyoxyethylene derivative) and three percent by volume G-2800 (manitol dioleate propylene oxide derivative) in 95 volumes of distilled water as an emulsifying diluent in the bacteriological examination of edible fats, using standard plate count technique, is recommended. The emulsified oil inoculum will become dispersed in the agar and other differential media so that a reasonably accurate estimation of the contaminating bacterial flora may be made. This combination of emulsifying agents will produce excellent emulsions with both solid and liquid fats, without significant foam formation, without deterioration upon autoclaving, without reaction with the differential dyes, and without apparent interference in the nutrition and differential growth of the bacteria.

The authors wish to express their sincere appreciation for the helpful suggestions received from Mr. Sereck

TABLE 2

Comparison of Distilled Water Inoculum and Detergent Inoculum Plate Counts on Dried Brewer's Yeast and Ground Pharmaceutical Gelatin Experimentally Contaminated with Staphylococcus aureus and Proteus morganii

	Distilled Water Inoculum			Detergent Inoculum		
	S. aureus	*P. morganii*	% Gas	*S. aureus*	*P. morganii*	% Gas
Gelatin No. 1	30,000	3,000	5%	30,600	3,000	5%
Gelatin No. 2	29,400	3,000	5%	30,000	2,940	5%
Gelatin No. 3	31,200	2,940	5%	30,900	3,000	5%
Yeast No. 1	29,200	2,880	5%	28,800	3,000	5%
Yeast No. 2	31,200	3,000	5%	30,000	3,000	5%
Yeast No. 3	30,000	3,000	5%	31,000	3,240	5%
Yeast No. 4	31,800	3,120	5%	30,000	3,090	5%

H. Fox, Technical Director, Gelatin Products Division, R. P. Scherer Corporation.

REFERENCES

1. American Public Health Association. *Standard Methods for the Examination of Dairy Products*, 8th Ed., 1941, 277 pp.
2. American Public Health Association and the American Water Works Association. *Standard Methods for the Examination of Water and Sewage*, 8th Ed., 1943, 288 pp.
3. Armour Laboratories (Armour and Company), Chicago, Illinois, Personal communication.
4. Breed, R. S., Murray, E. G. D., Hitchens, A. P., et al. *Bergey's Manual of Determinative Bacteriology*, 6th Ed., 1948, The William and Wilkins Company, Baltimore, Md., p. 884.
5. Ibid. p. 1303.
6. Brewer, J. H. Problems involved in the sterility testing of nonaqueous pharmaceutical preparations, *Abstracts, 47th General Meeting, Society of American Bacteriologists*, Philadelphia, Pa. (May 13-16, 1947).
7. Dubos, R. J. Effect of long chain fatty acids on bacterial growth. *Pro. Soc. Exptl. Bio. Med.*, **56**, 15491 P (1946).
8. Federal Register, Title 21 Food and Drugs, Chap. I, part 141, p. 2117 (April 4, 1947).
9. Harrison, F. C., and Sadler, W. Yellow discoloration of halibut oil. *Food Ind.*, **1**, 308 (1929).
10. Lee, M., and Chandler, A. C. A study of the nature, growth and control of bacteria in cutting compounds. *J. Bact.*, **41**, 378 (1941).
11. Quisno, R., Gibby, I. W., and Foter, M. J. Neutralizing medium for evaluating the germicidal potency of the quaternary ammonium salts. *Am. J. Pharm.*, **118**, No. 9, 320 (Sept., 1946).
12. Recommendations of the Committee of Ampul Preservatives of the American Pharmaceutical Manufacturer's Association. *Drug Trade News*, **23**, No. 5, 45 (March 8, 1948).
13. Renault, M. B. *Micrococcus petrolei* from oil bearing rocks. Compt rend. Acad. Sci., **124**, 1315 (1897).
14. Tausson, W. O. Naphthalin als Kohlenstoffquelle fur Bakterien, *Planta*, **4**, 214 (1927).
15. Winslow, C. E. A., and Winslow. *Systematic Relationship of the Coccaceae*, John Wiley and Sons, New York, N. Y. (1908).
16. ZoBell, C. E. *Desulfovibrio halohydrocarbonoclasticus* from oil bearing rocks (U. S. Patent No. 2, 413, 278). *Science News Letter*, p. 24 (Jan. 11, 1947).

Yield of Edible Portion of Chicken and Various Meats Cooked by Different Home Methods[a]

LUCY M. ALEXANDER and GRACE E. SCHOPMEYER

Bureau of Human Nutrition and Home Economics, Agricultural Research Administration, U. S. Department of Agriculture, Washington 25, D. C.

Stewing hens, roasting chickens, beef chuck pot roast, pork loin chops, and liver of beef, calf, and pork were cooked by different household methods (boiling, simmering, roasting, braising, frying). Data on yields of various cooked edible portions are presented and discussed in relation to shrinkage, or loss of weight, and to retention of moisture.

This paper is the second of a series of reports *(1)* designed to supply much-needed information on the yield of cooked edible portion, particularly muscle, obtained from poultry and various meats. Presented here are data on cooking time, shrinkage or loss of weight, and yield of cooked edible portion of stewing and roasting chickens, beef chuck pot roast, pork loin chops, and liver of beef, calf and pork. Many of the observations were made in connection with an investigation of the effects of cooking on the vitamin and mineral content of 23 foods *(5)*—a study in which each food was cooked by two home methods and in quantities sufficient to provide six servings. Cooking utensils were of the type commonly used in homes in this country.

[a] This research was supported in part by an allotment made by the Secretary of Agriculture from Special Research Funds (Bankhead-Jones Act of June 29, 1935).

Review of Literature

Published information relating cooking method to yield of edible portion for chicken is summarized in Table 1, and for beef, pork, and liver in Table 2.

TABLE 1

Review of Published Reports Concerning Yield of Edible Portion of Chicken Cooked by Different Methods (Figures in parentheses were calculated)

Class of chicken	Cooking method	Weight, raw		Shrinkage based on weight:		Yield of cooked edible portion based on weight:		Authors, and reference number
		N. Y. dressed	Other	N. Y. dressed	Other	N. Y. dressed	Other	
		pounds	*pounds*	*percent*	*percent*	*percent*	*percent*	
Stewing hen	No data	104	78.75[b]	(28.9)	38.2	(24.3)[c]	33.0[c]	National Turkey Federation *(10)*
Roaster (frozen)	Roasted, uncovered, at 300° F.,	3.74	(2.46)[d]	(14.5)	(22.0)	30.2[e]	(46.0)[e]	Lowe *(6)*
	thigh, 190° F.	4.116	(2.71)[d]	(14.6)	(22.2)	29.9[e]	(45.4)[e]	
Roaster	Roasted	4.14	3.34[f]	.....	25.9	46.8[g]	58.0[g]	Maw *(7)*

[b] Table dressed weight. [c] Boned white and dark meat, without giblets. [d] Drawn weight, without neck or giblets. [e] Edible meat (excluding neck and giblets). [f] Drawn weight, as ready for cooking. [g] Cooked meat, skin and fat.

TABLE 2

Review of Published Reports Concerning Shrinkage and Yield of Edible Portion of Beef, Pork, and Liver Cooked by Different Methods (Figures in parentheses were calculated)

Kind and cut of meat	Cooking method	Weight, raw	Fat content of raw meat	Cooking time	Shrinkage	Yield cooked edible portion	Authors, and reference number
Beef			*percent*	*min./lb.*	*percent*	*percent*	
Choice No. 1 grade steer, chuck	Roasted, without water; well done, 82° C.	.....	.....	51	36	.....	Burnett and Shalla *(3)*
	Roasted, with water; well done, 82° C.	.....	.....	39	35	.....	
Beef							
Spencer Roll	Roasted, without water; well done, 84° C.	.....	.....	37	31	.....	
	Roasted, with water; well done, 84° C.	.....	.....	25	48	.....	
Beef							
Round, pot roast[h]	Browned in 9 gm. fat; cooked covered; water added, well done	966.87 gm.	8.15	(84.5)	43.62	(56.38)	Grindley and Emmett *(4)*
		1,041.33 gm.	4.91	(78.3)	46.36	(53.64)	
Beef							
Topside	Boiled	1,500 gm.	.....	(63.4)	39.5	.....	McCance and Shipp *(8)*
Pork							
Loin chops	Broiled; well done, 80° C.	45 lb.	.....	8.0[i]	30	(66.7)	Burnett and Shalla *(3)*
Pork							
Rib and loin chops, cut 1 inch thick	Braised, without water; well done, 84° C.	6.91 oz.	.....	15.66[j]	20.15	60.48	McLachlan *(9)*
	Broiled at 175° C.; well done, 84° C.	6.12 oz.	.....	33.90[j]	37.83	46.89	
Liver, ox							
Pieces 40 to 60 grams each	Steamed	.....	.....	7.0[j]	21.0	.....	McCance and Shipp *(8)*
		.....	.....	12.0[j]	29.0	.....	
		.....	.....	20.0[j]	34.5	.....	

[h] Lean with all bone, gristle, and most of visible fat removed. [i] Cooking time per chop. [j] Total time for quantity cooked.

Experimental Procedure

Weights of raw and cooked muscle of stewing hens, beef chuck ribs, and pork loin, also weights of raw and cooked liver were obtained in the course of preparing these foods for chemical analysis *(5)*. The sampling procedures *(5)* were pertinent to studies of the effects of different methods of cooking on the yield of component parts of a cut, as for example, muscle, or fat. By dissecting the raw sample into muscle, skin, fat, and other parts, and assuming the same proportionate physical composition in corresponding and/or adjacent portions designated for cooking, a rough estimate was made of the weight of muscle and other components of the sample being cooked. Then, on comparing estimated weights when raw with actual weights when cooked and dissected, the effect of cooking procedures was investigated on muscle, fat, or other portions separately, although they were cooked together in their natural state, that is, as part of a chicken, a pot roast, or a chop.

Chicken—stewing hens. Three experiments were conducted as follows: (a) Simmering disjointed was compared with boiling disjointed, using 16 hens (all chicken drained and cooled separately from the broth). Eight of the hens were disjointed, then backs and breastbones were divided longitudinally with a saw so that the 16 halves could be paired for sampling 8 raw and 8 cooked (4 simmered, and 4 boiled) *(5)*. Without raw sampling, 4 hens were simmered and 4 boiled in covered pans until the meat was tender when pierced with a skewer. The published procedures *(5)* for cooling the cooked birds and obtaining the weights of the various portions were followed.

(b) Simmering whole or disjointed (all chicken cooled in the broth) was compared with (a) using 7 hens. They were simmered in covered pans until the meat was tender when pierced with a skewer, and the joints of whole birds had softened enough to permit easy separation into serving pieces. The cooked birds were drained and weighed, returned to the broth, and held under refrigeration at 35 to 45° F. (1.5 to 7° C.) for 16 to 40 hours, and again drained and weighed. They were then separated into various portions and these were weighed.

(c) Oven-braising whole, with added broth, at 350° F. (177° C.) was compared with (a) and (b) using 2 hens. Each was steamed partly done (2 hours), weighed, stuffed with seasoned bread crumb stuffing, weighed again, and placed in a roasting pan together with 1 cup of broth from the steamer. In this roasting pan, covered with a lid, cooking was continued in a moderate oven 350° F. (177° C.) until the meat was tender when pierced with a skewer and the joints had softened. The cooked birds containing the stuffing were weighed, cooled overnight under refrigeration at 35 to 45° F. (1.5 to 7° C.) and weighed again. The stuffing was then removed and weighed, after which the birds were separated into various portions and the portions weighed.

Chicken, roasters. A hen and 2 cockerels were cooked. In preparation, the chickens were weighed, stuffed with seasoned bread crumbs, and weighed again. The hen was rather lean, therefore it was braised in a covered pan, in a moderate oven at 350° F. (177° C.). No water was added. The cockerels were roasted in uncovered pans at 320° F. (160° C.) with no added water. At intervals they were turned from side to side and breast up, for even cooking. All the chickens were cooked until the meat was tender when pierced with a skewer and the joints had softened. When cooked the chickens were treated in essentially the same manner as the oven-braised stewing hens.

Beef. The chuck cuts of U. S. Choice steer beef used consisted of the third, fourth, and fifth ribs, numbering from the fore end, taken from the right and left sides of the same carcass *(5)*. For the raw sample, the fourth

rib and two slices of meat (¾ inch thick) cut from the outside of the third and fifth ribs were removed, separated into muscle, fat, and bone, and the portions weighed *(5)*. Remaining portions of the chuck cuts, that is, the third and the fifth ribs were braised as pot roasts—those from the left side of the animal without added water and those from the right side with 1½ cups water added to each. When cool the pot roasts were separated into muscle, fat, and bone, and the portions weighed *(5)*. Similarly, a pair of third, fourth, and fifth chuck ribs of beef of unreported history were sampled raw and cooked.

Pork. A center loin of pork was cut so that there were 12 chops ¾ inch thick alternating with 12 chops ⅜ inch thick. The ⅜ inch chops, used for the raw sample, were separated into muscle, and fat and bone, and the portions weighed. The ¾ inch chops were taken in alternate order for the two cooking procedures —braising and frying in their own fat. This sampling resulted in 3 loin and 3 rib chops in each portion for cooking. The fried and the braised chops were separated into muscle, and fat and bone, and the portions weighed *(5)*.

Liver: beef, calf, and pork. Slices of liver ½ inch thick were cut in thirds; one third of each slice was taken for the raw sample and the other two thirds for the two cooking methods used—frying and braising without added water *(5)*.

Calculations

Cooking time. All periods during which heat (gas) was applied to the foods were counted as cooking time. The number of minutes of cooking per pound was calculated by dividing the total number of minutes by the weight of the raw food when ready to cook. The weight of stuffing was not included in the ready-to-cook weight of stuffed chickens for the calculation of cooking time.

Shrinkage. Shrinkage was considered to be 1) the sum of losses during cooking and cooling, or 2) the difference between loss of weight during cooking and gain of weight during cooling. Shrinkage percent was calculated on the weight of the food ready to cook. For chicken, the shrinkage was calculated also as percent of New York dressed weight (bled, picked, but not drawn, and including head and feet) when this weight was available.

Cooking shrinkage was considered to be the difference between the weights of the hot drained cooked foods and their respective weights when raw and ready to cook, except in the case of the stuffed chickens. To obtain the cooking shrinkage of stuffed chicken, the weight of juices from the bird absorbed by the stuffing was added to the difference between the weights of the raw stuffed bird and the cooked stuffed bird.

Change of weight (loss or gain) during cooling was considered to be the difference between the weights of the drained, cooked, cooled foods and their respective weights when hot at the end of the cooking period. Stuffed chickens were left stuffed during cooling.

Content of raw edible portion. For calculating the composition of the halves of the 8 stewing hens dissected raw, the weights of raw muscle, and of raw skin with adhering fat were calculated as percentages of the weight of the halves, bone in. From these percentages and the ready-to-cook, bone-in weights of the corresponding 8 halves used in cooking, estimates were made of the weights of the raw muscle and raw skin with adhering fat which were to be cooked. Similarly, the percentages of raw muscle and fat, obtained for the portions of beef chuck ribs dissected raw, were used to estimate the weights of these components in the cuts to be cooked. From the portions of pork loin dissected raw, the percentage of raw muscle determined was used for estimating the weights of raw muscle in the chops to be cooked.

Yield of cooked edible portion. For calculating the percentage yield of cooked muscle and other edible portions the weight bases for *chicken* were (a) New York dressed, (b) raw, ready to cook, bone in (excluding giblets and stuffing), and (c) estimated raw muscle and raw skin with adhering fat; for *beef chuck* and *pork loin* (a) raw, ready to cook, bone in, and (b) estimated raw muscle; for *liver,* raw, ready to cook.

Retention of moisture. Retention of moisture in the cooked muscle of chicken, beef, and pork and in cooked liver was calculated as a percentage based on the weight of the moisture in these portions after cooking in relation to the weight of the moisture they contained before cooking. The published data *(5)* on percent moisture content of these foods, raw and cooked, were used. The formula for calculating retention of moisture was as follows:

a = percent moisture in raw food

b = percent moisture in cooked food

$$\text{Percent retention} = \frac{b \times \text{weight of cooked food}}{a \times \text{weight of raw food}} \times 100$$

Results and Discussion

Chicken. Yields of cooked muscle were similar whether the stewing hens were boiled or simmered, and then cooled separately from the broth (Table 3). Furthermore, they were in reasonable agreement with published data *(10)*. When based on their estimated weights, raw (Table 3, footnote m), the yield of cooked muscle was 69.6 percent, and of skin with adhering fat 60.8 percent.

The simmered hens, cooled in broth, gained during cooling from 10.6 to 12.0 (average 11.8) percent of their weight when ready to cook, bone in; this gain offset about ⅓ of the weight lost in cooking. By contrast, using the same weight base, the boiled and simmered birds which were cooled separately from the broth, lost from 2.5 to 4.3 (average 3.8) percent in addition to the weight lost during cooking. As Table 3 shows, shrinkage after cooking and cooling was less and the yield of muscle greater for the birds cooled in broth than for those cooled separately from the broth —a result in line with findings on gain in weight reported for cured hams cooked in water and cooled in broth *(11)*.

TABLE 3

Yield of Edible Portion (Excluding Giblets) of Chickens Cooked by Different Methods

Class of chicken and method of cooking	Number of chickens	Average weight		Average cooking time per pound[k]	Average shrinkage based on weight		Yield of cooked edible portion				Description and source of raw sample
							Muscle based on weight		Skin with fat based on weight		
		N. Y. dressed	Ready to cook[k]		N. Y. dressed	Ready to cook[k]	N. Y. dressed	Ready to cook[k]	N. Y. dressed	Ready to cook[k]	
		pounds	*pounds*	*minutes*	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	
Stewing hen											
Simmered	2[l]	4.98	3.67	66.1	28.8	39.0	24.1	32.6	9.6	13.0	Rhode Island Red hens, average age 92 weeks, from Bureau of Animal Industry, Beltsville, Md., January 1943.
Boiled	2[l]	4.87	3.45	56.4	24.8	35.1	23.7	33.6	8.8	12.5	
Simmered	4	5.19	3.60	58.7	23.8	34.3	25.0	36.0	9.1	13.2	From Washington, D. C. market, January 1943.
Boiled	4	4.80	3.31	56.5	23.6	34.2	23.7	34.5	9.4	13.7	
Simmered	1	.....	4.35	59.3	.....	24.7	.....	39.8	.....	19.9	Golden Leghorn hen, 96 weeks old
cooled in broth	1	.....	3.51	75.8	.....	25.9	.....	40.4	.....	14.1	White Leghorn hen, 148 weeks old From Bureau of Animal Industry, Beltsville, Md., February 1941.
	5	.....	2.81	103.0	.....	23.1	.....	40.8	.....	17.8	From Washington, D. C. market, February, March, 1941.
Oven braised	2	.....	2.73[m]	88.1	.....	41.5	.....	35.5	.....	9.3	White Leghorn hens, average age 96 weeks, from Bureau of Animal Industry, Beltsville, Md., February 1941.
Roaster											
Oven braised	1	.....	2.88[m]	41.3	.....	26.5	.....	46.6	.....	11.0	Rhode Island Red hen, 41 weeks old, from Bureau of Animal Industry, Beltsville, Md., February 1941.
Roasted	1	.....	4.86[m]	36.4	.....	34.3	.....	43.8	.....	6.7	Rhode Island Red cockerel, 36 weeks old
	1	.....	5.58[m]	35.5	.....	36.6	.....	43.7	.....	6.4	Cornish cockerel, 44 weeks old From Bureau of Animal Industry, Beltsville, Md., April 1947.

[k] Bone in; giblets excluded. [l] 4 chicken halves were considered equivalent to 2 whole chickens. In the 8 halves simmered and boiled, the total weight of raw muscle was estimated as 6.76 pounds and of skin with adhering fat 2.99 pounds; the corresponding halves sampled raw provided the basis for this estimation. [m] Excludes neck and stuffing as well as giblets.

The oven-braised stewing hens yielded about the same proportion of cooked muscle as the boiled and simmered fowls cooled separately from the broth, and less skin and adhering fat than any of the other birds of this class.

With the small number of roasting chickens cooked (Table 3), conclusions cannot be drawn as to whether differences in yield of cooked muscle and of skin with adhering fat were due to cooking method or to other factors. For the oven-braised roasting hen, the yield of cooked muscle plus skin and fat as well as the shrinkage were in reasonable agreement with data published by Maw *(7)*. Yields of cooked muscle obtained from the roasted cockerels were slightly smaller than yields reported by Lowe *(6)* for roasters which were lighter in weight and, presumably, younger. The higher proportionate yield of cooked muscle for roasting chickens, as compared with that for stewing hens, was in general accord with published data *(6, 10)*.

For a study of the influence of shrinkage on the combined yield of cooked muscle and skin with adhering fat, calculated as percentage of raw weight, ready to cook, bone in, the data for each of the 24 chickens (Table 3) are presented in Figure 1.

According to the data in Figure 1, the yield of cooked muscle plus skin with adhering fat was, in general, inversely related to shrinkage, that is, the smaller the shrinkage the higher the yield. These results confirm previous findings *(1)*. What proportion of the shrinkage was derived from muscle and what from other components of chicken was not determined.

Beef. Slightly more time per pound, ready-to-cook weight, bone in, was required for braising beef chuck ribs when water was added than when the meat was cooked in its own juice (Table 4). As percentage of this weight base, shrinkage was reduced by cooking with water, yields of cooked muscle were not consistently affected, but yields of cooked fat appeared to be increased.

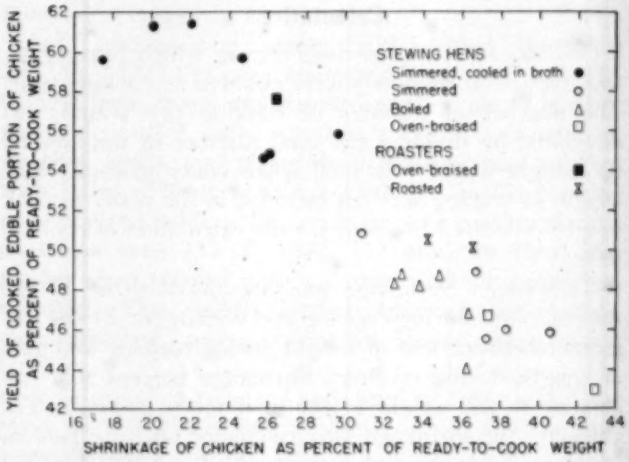


FIG. 1. Dot-chart showing relation of shrinkage of chicken to yield of cooked edible portion. Each dot represents one chicken, except that for two chickens 30.9 percent shrinkage and 50.8 percent yield were observed.

For definition of ready-to-cook weight, see the footnotes to Table 3. Cooked edible portion consists of muscle plus skin with adhering fat.

As percentages of the estimated weight of raw muscle, the data are consistent in showing that adding water reduced the yield of the cooked muscle portion of the cut. Comparing the same cuts cooked with and without water, the proportionate yield of cooked muscle to esti-

TABLE 4

Yield of Edible Portion of Chuck Ribs of Beef and of Loin of Pork, Cooked by Different Methods

Kind and cut of meat and method of cooking	Number of samples	Average weight, raw		Average cooking time[a]	Average shrinkage[a]	Yield of cooked edible portion		
		Ready to cook, bone in	Muscle[a] only			Muscle, based on weight		Fat, based on weight
						Ready to cook, bone in	Raw muscle only	Ready to cook, bone in
		pounds	*pounds*	*min./lb.*	*percent*	*percent*	*percent*	*percent*
Beef, U. S. Choice steer:								
Third and fifth chuck ribs, left side, braised, no water	2	4.08	2.23	54.5	38.2	35.1	64.2	14.5
Third and fifth chuck ribs, right side, braised, water added	2	4.17	2.46	58.6	36.6	36.9	62.5	15.0
Beef:								
Third and fifth chuck ribs, left side, braised, no water	2	4.23	2.63	41.2	39.9[b]	37.1	59.6	13.1
Third and fifth chuck ribs, right side, braised, water added	2	4.14	2.60	44.9	37.9[b]	35.5	56.6	15.3
Pork:								
Three loin and three rib chops, cut ¾ inch thick, fried	1	1.99	1.08	7.5	31.7	39.4	72.2	.....
Three loin and three rib chops, cut ¾ inch thick, braised, no water	1	1.96	1.07	15.3	31.0	35.5	65.2	.....

[a] Estimated. [b] Based on weight ready to cook, bone in. [b] Data for 1 sample.

mated raw muscle appeared to be higher in the fatter cuts. Furthermore, the addition of water reduced the yield of cooked muscle proportionately more in the leaner cuts than in the fatter ones. These results agree in general with the published findings *(3)* which indicate that the addition of water to choice No. 1 grade steer beef chuck made a difference of only 1 percent (36 vs. 35 percent) in the shrinkage, therefore probably also in the yield, whereas for the presumably much leaner Spencer Roll, the shrinkage was increased 17 percent (31 vs. 48 percent) when water was added—a difference that would be expected to influence the yield accordingly. When pot roasts were braised with water added (Table 4), the smaller yield of cooked to raw muscle from the leaner cuts was in accord with published findings *(4)* which indicate that the leaner the round of beef the more it shrinks and less it yields.

Results obtained from these few samples point up the need for research in adapting cooking method to degree of fatness of beef. Cooking methods suited to well-fatted beef probably need to be modified for leaner and cheaper beef. Furthermore, studies of the proportion of raw lean, fat, and bone in retail cuts of different grades of beef *(2)* ought to be extended to include yield of these portions after cooking. This would provide additional information on the basic principles of selecting meat.

Pork. The yield of cooked muscle as percentage of both the ready-to-cook, bone-in weight and the estimated weight of raw muscle was consistently greater in fried chops than in those braised without water (Table 4). The difference in yield probably was due to the more thorough cooking of the braised chops, which were steamed until tender; the fried chops were cooked only until red color disappeared throughout the meat.

Because frying and broiling are related "dry heat" cooking methods, data on the fried pork chops (Table 4)—cooking time, shrinkage and yield—were compared with corresponding published data for broiled pork chops *(3, 9)*. The cooking times are dissimilar, probably due to variations in the size of the cooking sample, the thickness of the chops, and the methods of cooking. The data on shrinkage (Table 4) were in reasonable agreement with Burnett and Shalla's *(3)*, and less than those reported by McLachlan *(9)*. Yield of cooked muscle only (Table 4) could not be compared with combined yield of cooked muscle and fat as published *(3, 9)*.

Data on cooking time and shrinkage for pork chops braised without water (Table 4) do not agree with those of McLachlan *(9)*. Weights of the ready-to-cook samples differed greatly—the meat may have been cooked to different degrees of doneness.

TABLE 5

Yield of Cooked Edible Portion of Liver Cooked by Different Methods, Expressed as Percentage of Ready-To-Cook Weight

Kind and cooking method	Weight, ready to cook[c]	Cooking time	Shrinkage	Yield cooked
	pounds	*min./lb.*	*percent*	*percent*
Beef liver:				
Fried	1.31	9.9	32.1	67.9
Braised, no water	1.50	10.0	39.0	61.0
Calf liver:				
Fried	1.38	13.8	33.0	67.0
Braised, no water	1.38	8.3	33.2	66.8
Pork liver:				
Fried	1.45	11.0	25.5	74.5
Braised, no water	1.48	8.1	23.8	76.2

[c] One lot cooked for each kind and method.

Liver. Shrinkage of liver when cooked (Table 5), was in reasonable accord with published data *(8)*. Because so few samples were used, and so little pertinent information on liver has been published, conclusions cannot be drawn regarding the comparative effect of frying and braising on yield of cooked liver.

Yield and moisture retention of cooked muscle and liver. According to these data, yields of cooked muscle and liver, as percentages of estimated weights raw, were: for Rhode Island Red stewing chicken muscle (average boiled and simmered), 69.6; for U. S. Choice steer beef muscle braised without water, 64.2; for pork muscle, braised without water and fried, respectively, 65.2 and 72.2; and for liver (average of beef, calf, and pork, Table 5), braised without water, 68.0, fried 69.8. In an attempt to explain the general trend shown by these yield data, they are presented in Table 6 together with the published moisture content of the foods before and after cooking *(5)* and the percent retention of moisture in the cooked food.

In the raw state, muscle and liver were similar in moisture content (Table 6). Cooking reduced the moisture in all these foods, but not to the same propor-

TABLE 6

Moisture Content and Retention, and Yield of Muscle and Liver Cooked by Different Methods

Food and method of cooking	Moisture			Yield cooked
	Content		Retention cooked	
	Raw	Cooked		
	percent	*percent*	*percent*	*percent*
Chicken muscle (Rhode Island Red stewing hen):				
Boiled	70.7	59.2	58.3	69.6[r]
Simmered				
Liver (average for beef, calf, and pork):				
Fried	71.0	56.1	55.2	69.8
Braised, no water		56.9	54.5	68.0
Pork loin muscle:				
Fried	70.1	46.4	47.8	72.2[r]
Braised, no water		47.3	44.0	65.2[r]
Beef chuck muscle (U. S. Choice steer):				
Braised, no water	71.6	46.0	41.3	64.2[r]

[r] Percent estimated weight raw muscle.

tionate extent, as the retention values showed. For the different foods when cooked by boiling and simmering and by braising, yield was directly related to the retention of moisture. This direct relationship between yield and retention was confirmed when fried pork muscle was compared with braised pork muscle, and similarly, fried liver with braised liver. However, when fried pork muscle and fried liver were compared, yield was inversely related to retention of moisture.

Summary and Conclusions

Twenty-one stewing hens (fowls), 3 roasting chickens, 4 pairs of chuck rib pot roasts of beef, and 12 pork chops were cooked by different home methods, and separated into muscle, skin with adhering fat, and bone. Beef, calf, and pork liver were also cooked by various methods. Cooking time, shrinkage, and yield were determined.

For all these foods the smaller the shrinkage the greater was the yield of cooked edible portion based on weight when ready to cook.

The yield of cooked edible portion (muscle plus skin with adhering fat) of stewing hens was increased by cooling the birds in the broth in which they were cooked. Roasting chickens gave larger yields of cooked muscle than stewing hens, in proportion to their weight ready to cook, bone in.

As a group, the yields of cooked muscle of stewing hens (cooled separately from the broth), beef chuck, and pork chops were similar—ranging from 33 to 39 percent of their ready-to-cook weights, bone in; when calculated as percentage of their estimated weights of raw muscle only, the range in yields of cooked muscle was from 64 to 72 percent. Liver yielded on the average 69 percent of its weight before cooking. When these foods were boiled, simmered, or braised, their yields were directly related to the retention of moisture, but this relationship was inverse when liver and pork muscle were fried.

Acknowledgments

Jessie C. Lamb, Food Specialist, and Ernestine Garofalo Law and Bernice Kluttz McGeary, former Food Specialists of the Food and Nutrition Division of the Bureau of Human Nutrition and Home Economics, assisted with the cooking procedures. Richard L. Hiner, Animal Husbandman, Bureau of Animal Industry, assisted in working out the techniques of sampling beef chuck and pork loin, and cut the samples of these meats and of pork liver.

The Bureau of Animal Industry provided pork liver and the chickens of known history.

LITERATURE CITED

1. Alexander, L. M., Schopmeyer, G. E., and Marsden, S. J. Yield of cooked edible portion of young roasted turkey. *Poultry Sci.* **27**, 579 (1948).
2. Bull, S. The economy of retail cuts of different grades of beef. Consumers' Research *Bull.* **20** (3) : *22* (1947).
3. Burnett, F., and Shalla, E. M. Determination of the amount of edible meat as affected by methods of preparation. *J. Am. Dietet. Assoc.*, **6**, 239 (1930).
4. Grindley, H. S., and Emmett, A. D. Studies on the influence of cooking upon the nutritive value of meats at the University of Illinois, 1903-1904. U. S. Dept. Agr. Off. Expt. Sta. *Bull.* No. **162**, 230 pp. (1905).
5. Hewston, E. M., Dawson, E. H., Alexander, L. M., and Orent-Keiles, E. Vitamin and mineral content of certain foods as affected by home preparation. U. S. Dept. Agr. *Misc. Pub.* No. **628**, 76 pp. (1948).
6. Lowe, B. Edible meat from two weights of roasters . . . comparing yields from 43 to 47-pound and 48 to 54-pound classes of roasters. *U. S. Egg and Poultry Mag.* **47**, 95 (1941).
7. Maw, W. A. Factors influencing market quality and consumer value in poultry meat stock. *U. S. Egg and Poultry Mag.* **45**, 204 (1939).
8. McCance, R. A., and Shipp, H. L. The chemistry of flesh foods and their losses on cooking. [Gt. Brit.] Med. Research Council, *Special Rept.* Ser. **187**, 146 pp. (1933).
9. McLachlan, H. Standardizing methods of broiling beef steaks and methods of cooking pork chops. (Thesis, M.S., Univ. Mo.) [Abstract in Report of Review Comm., Conference on Cooperative Meat Investigations, vol. 2, Ref. No. 71, 1937. Processed.]
10. National Turkey Federation. Turkey Handbook. 83 pp. Mt. Morris, Ill. (1947).
11. Purdy, D. I. Factors influencing shrinkage in cooked hams. 79 pp. (Thesis, M.S., Univ. Minn., 1926).

Comparison of Light vs. Darkness for Storing Butternut Squashes[a]

ARTHUR D. HOLMES, ALBERT F. SPELMAN AND ROBERT T. WETHERBEE

Massachusetts Agricultural Experiment Station, Amherst, Mass.

Two comparable lots of fully matured Butternut squashes were stored for eight weeks under the same conditions except one lot was stored in darkness and the other in controlled, continuous artificial illumination. The water content of the squashes remained fairly constant. Carotene increased during each of the four-weeks' periods. The amount of reduced ascorbic acid and total sugars increased during the first four-weeks' periods, but did not increase during the second four-weeks' storage. In all instances the amount of reduced ascorbic acid, carotene and total sugars was larger in the squashes stored under artificial illumination than in comparable squashes stored in darkness.

Squashes are an important crop in the New England area and much time and attention have been devoted to developing varieties and strains which are particularly suited to local requirements. The Butternut squash has been developed quite recently and has gained considerable acceptance both with market gardeners and the consuming public. During the summer, while it is in the immature state, it may be used as a summer squash, and after it has fully matured it is used during the fall and early winter months as a winter vegetable. At both stages of growth it is rich in carotene. Holmes, Spelman and Jones *(5)* reported 3.31 mg. of carotene per 100 g. for immature Butternut squashes as compared with .06 mg. for Early White Bush Scallop, .16 mg. for Cocozelle Vegetable Marrow, .33 mg. for Early Summer Crookneck, and .36 mg. per 100 g. for Zucchini Grey which were being eaten as a summer vegetable. In a study of variation in composition of winter squashes, Holmes, Smith and Lachman *(7)* found from 6.9 mg. to 11.8 mg. with an average of 8.5 mg. of carotene per 100 g. for Butternut squashes and .9 mg., 3.4 mg., 3.6 mg. and 5.5 mg. of carotene per 100 g. respectively for Des Moines, Blue Hubbard, Buttercup and Golden Cushaw squashes. Previously, Holmes and Spelman *(6)* compared the composition of Blue Hubbard, Butternut, Golden Cushaw and Delicious squashes that had been in storage from harvest until the middle of February and reported 7.94 mg. of carotene per 100 g. in Butternut squashes and 2.22 mg., 3.90 mg. and 7.12 mg. of carotene per 100 g. respectively in Blue Hubbard, Delicious and Golden Cushaw squashes. These high values for winter squashes suggest the possibility that the carotene content of these squashes may have increased during winter storage, particularly since Snyder and Lachman *(13)* examined seven varieties of carrots during cold storage from November to April and found that in each variety the carotene content increased during cold storage. Also, McKillican *(11)* reported that a study of three varieties of carrots for two years showed that the carotene content on the dry matter basis was greater at the end of the storage period than at the beginning. Some market gardeners store squashes in greenhouses in the full daylight and sunshine. Others store their squashes in dark squash houses. This study was undertaken to compare the composition of squashes stored in darkness with the composition of those stored under controlled illumination.

Experimental

The squashes used in this study were produced at the Waltham Field Station by R. E. Young in his studies of the effect of various cultural conditions upon the yield and quality of Butternut squashes. When the squashes arrived at the laboratory they were washed to remove all debris and the tip of the stem end was dipped in molten paraffine to form a protective covering. The well-colored, fully mature squashes were divided into two comparable lots of sixty-five each, which averaged 1190.9 gm. and 1192.5 gm. per squash. The two lots were separated by a one-quarter inch cardboard partition. One lot was continuously in the dark. The other was continuously illuminated by four 20-inch, white flourescent bulbs placed beneath a 46-inch by 49-inch metal reflector suspended 24 inches above the squashes. A Friez automatic recording hygrothermograph continuously measured the temperature and humidity. The extreme temperatures were 11° C. (52° F.) and 24° C. (75° F.) but for more than 60 percent of the period the temperature remained between 15° C. (59° F.) and 20° C. (68° F.). The extreme values for relative humidity were 26 percent and 52 percent, but for 90 percent of the time the humidity ranged between 30 percent and 40 percent. Daily temperature readings showed a difference of only one degree between the atmospheric temperatures surrounding the two lots of squashes and the higher temperature alternated between the two lots as the outdoor temperature fluctuated from time to time.

Typical specimens were selected before the squashes were divided into two lots. Thereafter at four-week intervals typical specimens were selected from both groups. These were assayed for water, reduced ascorbic acid, carotene and total sugars. The assays were made in accordance with the methods adopted by the Association of Official Agricultural Chemists *(1)*.

Results and Discussion

The results of the analyses of typical Butternut squashes selected at regular intervals during the storage period are reported in detail in Table 1. With the exception of squash No. 52 the amount of water in the individual squashes varied by less than 5.0 percent but the means for the water content of the squashes in the different groups varied by only about one percent. Judged by these data the amount of water in the squashes did not change materially during eight weeks'

[a] Contribution No. 712, Massachusetts Agricultural Experiment Station.

TABLE 1

Results of Analyses of Butternut Squash

Squash No.	Storage Conditions	Water	Dry Basis		
			Reduced Ascorbic Acid	Carotene	Total Sugars
		%	mg./100 g.	mg./100 g.	%
Values immediately before storage					
18	----	84.9	57.7	31.8	45.0
98	----	82.3	57.3	18.6	46.0
107	----	86.9	41.2	28.2	55.0
115	----	83.2	57.1	24.4	50.4
123	----	85.4	42.5	27.4	56.2
	Average	84.5	51.2	26.1	50.5
Values after four weeks' storage					
50	Light	86.0	81.4	50.0	58.4
56	Light	84.1	76.7	37.7	57.8
102	Light	83.5	78.4	57.9	59.0
108	Light	83.5	53.9	25.5	58.8
120	Light	85.8	84.5	49.3	54.1
	Average	84.6	75.0	44.1	57.6
25	Darkness	85.0	62.7	21.3	58.6
72	Darkness	83.3	58.2	34.2	57.0
73	Darkness	83.3	69.9	25.9	56.0
61	Darkness	83.6	43.3	22.6	54.6
122	Darkness	87.3	64.5	48.8	57.1
	Average	84.5	59.7	30.5	56.7
Values after eight weeks' storage					
3	Light	81.0	51.5	74.2	56.4
41	Light	84.1	46.5	70.4	60.8
43	Light	85.3	59.2	76.2	59.0
58	Light	83.9	64.0	36.0	56.8
110	Light	84.3	42.7	51.6	57.4
	Average	83.7	52.8	61.7	58.1
6	Darkness	85.0	35.4	44.7	58.8
9	Darkness	86.5	43.0	40.0	57.2
31	Darkness	84.8	80.3	44.1	56.0
40	Darkness	83.8	30.2	50.6	52.4
52	Darkness	90.7	21.5	62.4	49.6
	Average	86.2	42.1	48.4	54.8

storage in either a light or a dark room. These results are in accord with those of Phillips *(12)* who concluded from his studies that, "It appears that the water content depends on the balance between the loss of water by evaporation and its gain by respiration. The Blue Hubbard lost fresh weight more slowly than did the other varieties. Its water content increased markedly, that of the Buttercup only slightly, and that of the Butternut not at all."

The average amount of reduced ascorbic acid in the Butternut squashes when they were placed in storage was 51.2 mg. per 100 g. During the first four-week period it increased in both lots of squashes. At the end of four weeks' storage the amount of reduced ascorbic acid in the squashes stored in darkness had increased from 51.2 mg. to 59.7 mg. per 100 g., but that of the squashes stored under continuous illumination increased to 75.0 mg. per 100 g. Presumably the light caused more activity in these than occurred in the squashes stored in darkness. Apparently the physiological activity in the squashes that affected the amount of reduced ascorbic acid ceased during the second four weeks' storage period since the amount in the squashes at the end of eight weeks' storage was essentially the same as at the start and that of the squashes stored in darkness was decidedly less. The higher reduced ascorbic acid values for the squashes stored in the light are in harmony with the observation of Harding, Winston and Fisher *(4)* that significantly larger amounts of reduced ascorbic acid were found in oranges picked from the outside branches which were well exposed to sunlight. In this connection reference may be made to the observation of Hamner, Bernstein and Maynard *(3)* that variation in ascorbic acid content of tomatoes associated with differences in light intensity were relatively great. Also, Hamner and Maynard *(2)*, Maynard and Beeson *(10)*, and Koski, Webster and Kirch *(9)* have supplied evidence of the influence of light on ascorbic acid content of tomatoes.

The carotene content of the squashes at the beginning of the study averaged 26.1 mg. per 100 g. After four weeks' storage in darkness the specimens selected for assay contained 30.5 mg. per 100 g. and those stored in the light contained 44.1 mg. Considered on a percentage basis, the carotene content of the squashes stored in darkness increased 16.9 percent and the amount of carotene in the squashes stored in light increased 68.9 percent. At the end of eight weeks' storage in darkness, the amount of carotene had increased to 48.4 mg. per 100 g. or nearly twice that at the beginning of the study. During the same interval the squashes stored in light more than doubled their carotene content, i.e., the amount of carotene had risen to 61.7 mg. per 100 g. These increases in the carotene content of the squashes averaged 85.4 percent for the squashes stored eight weeks in darkness and 136.4 percent for the squashes exposed to controlled artificial illumination. These data indicate that physiological processes are active in Butternut squashes during winter storage. They also indicate that those processes, particularly as they apply to the carotene content of the squashes, proceed at a much greater rate when Butternut squashes are exposed to continuous illumination.

The total sugar value of the Butternut squashes under observation remained fairly constant throughout the experimental period. At the beginning of the study the average amount of total sugars in the squashes was 50.5 percent. During the first four weeks of storage the total sugars of the squashes stored in the dark increased 11.2 percent and the increase for the squashes stored in the light was 11.4 percent. At the end of eight weeks' storage the squashes stored in darkness contained 8 percent more total sugars than at the beginning of the study and the squashes stored under the artificial illumination contained 11.5 percent more total sugars. Since the amount of total sugars, after four weeks' storage and also after eight weeks' storage, was larger in the squashes stored in light than in the squashes stored in darkness, it is presumed that the physiological processes, taking place in the squashes during storage, were increased by the action of the continuous artificial illumination. This observation is in accord with results reported by Holmes, et al. *(8)* who found in a study of the effect of light during storage of Blue Hubbard squash that, at the end of four weeks' and fifteen weeks' storage, the amount of total sugars was larger in the squashes stored in light than in those stored in darkness, but this was not true at the end of sixty days' storage. Obviously, one would expect more pronounced and consistent effects of the action of light on Butternut than on Blue Hubbard squashes, for the outer skin or shell

of the latter is much thicker and more dense than that of the former. Phillips *(12)* also noted an increase in total sugars during storage of Butternut squashes. His values were 14.97 percent at harvest, 25.99 percent after two weeks' storage and 43.55 percent at the end of three months' storage.

Summary

One hundred and thirty well-colored, fully matured Butternut squashes that had been grown under experimental conditions were divided into two comparable lots. They were stored for eight weeks under the same conditions except one lot was stored in darkness and the other in controlled, continuous artificial illumination. The water content of the squashes remained fairly constant during the experimental period. The amount of reduced ascorbic acid in the squashes increased during the first four weeks and decreased during the second four weeks' period. The carotene increased during each of the four-weeks' periods. The total sugars increased during the first four-weeks' periods, but did not increase during the second four-weeks' storage. However, in all instances the amount of reduced ascorbic acid, carotene and total sugars was larger in the squashes stored under artificial illumination than in comparable squashes that were stored in darkness.

LITERATURE CITED

1. Association of Official Agricultural Chemists. Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists, 6th Ed., 1945. Association of Official Agricultural Chemists, Washington, D. C.
2. Hamner, K. C., and Maynard, L. A. Factors influencing the nutritive value of the tomato. A review of the literature. *U. S. Dept. Agri. Misc. Pub.* **502** (1942).
3. Hamner, K. C., Bernstein, L., and Maynard, L. A. Effects of light intensity, day length, temperature and other environmental factors on the ascorbic acid content of tomatoes. *J. Nutrition*, **29**, 85 (1945).
4. Harding, P. L., Winston, J. R., and Fisher, D. F. Seasonal changes in the ascorbic acid content of juice of Florida oranges. *Proc. Amer. Soc. Hort. Sci.*, **36**, 358 (1939).
5. Holmes, A. D., Spelman, A. F., and Jones, C. P. Ascorbic acid, carotene, chlorophyll, riboflavin and water content of summer squashes. *Food Research*, **10**, 489 (1945).
6. Holmes, A. D., and Spelman, A. F. Composition of squashes after winter storage. *Ibid.*, **11**, 345 (1946).
7. Holmes, A. D., Smith, C. T., and Lachman, W. H. Variation in composition of winter squashes. *Ibid.*, **13**, 123 (1948).
8. Holmes, A. D., Spelman, A. F., Rogers, C. J., and Lachman, W. H. Influence of light during storage on composition of Blue Hubbard squash. *Ibid.*, **13**, 304 (1948).
9. Koski, I. J., Webster, G. L., and Kirch, E. R. Ascorbic acid content of tomatoes. *Ibid.*, **9**, 386 (1944).
10. Maynard, L. A., and Beeson, K. C. Some causes of variations in the vitamin content of plants grown for food. *Nutrition Abstracts and Rev.*, **13**, 155 (1943-44).
11. McKillican, Mary E. The stability of carotene in carrots during storage. *Sci. Agri.*, **28**, 183 (1948).
12. Phillips, T. G. Changes in the composition of squash during storage. *Plant Physiol.*, **21**, 533 (1946).
13. Snyder, G. B., and Lachman, W. H. Carotene content of carrots. *Mass. Agri. Expt. Sta. Bull.*, **417**, 54 (1944).

Some Aspects of Trimethylamine Formation in Swordfish[a]

DAVID W. ANDERSON, JR., and CARL R. FELLERS

Department of Food Technology, University of Massachusetts, Amherst, Massachusetts

The effect of storage temperature microorganisms and chemical autolysis on trimethylamine formation are discussed. Although the total bacterial count of swordfish at low storage temperature increases, the formation of trimethylamine by the responsible microorganisms is greatly retarded. A microorganism identified as a member of the coliform group, isolated from decomposing fish, actively reduced trimethylamine oxide to trimethylamine. Chemical autolysis did not reduce the oxide.

The changes occurring in marine fish stored at various temperatures have been studied for a number of years. Recently, the measurement of increases in volatile bases, particularly trimethylamine, have received considerable attention as a measure of spoilage. Beatty and Gibbons *(2)* and Dyer *(5)* have reported trimethylamine values of fresh, salt water fish as a satisfactory measure for freshness. Hillig *(6)* stated that the trimethylamine test is not applicable to canned fish or to fresh water species. However, Sigurdsson *(9)* maintained that knowledge of the reliability of all tests for the quality of sea fish is limited owing to the striking lack of comparable data.

Although Suwa *(10)* isolated trimethylamine oxide from sea fish in 1909, it was not until 17 years later that Poller and Linnewah *(8)* observed that this compound was reduced to its corresponding amine during the bacterial decomposition of fish. Later, Beatty and Gibbons *(2)* and Labrie and Gibbons *(7)* showed that increases in trimethylamine ran parallel to increases in bacterial population. Tarr and Sunderland *(13)* conducted experiments indicating that trimethylamine values and bacterial population do not always increase proportionately. In a later paper, Tarr *(12)* found an inconstant relationship between trimethylamine content and bacterial population and further showed that not all bacteria are capable of reducing the oxide. Tarr *(11)*, quoting workers at his station, also reported that sterile fish muscle and sterile press juice do not reduce the oxide.

In order to make the determination of trimethylamine applicable to commercial use, Dyer *(4)* devised a colorimetric determination of trimethylamine as a picrate salt. Dyer *(5)* further improved this determination until he stated it was suitable for making large numbers of routine analyses.

The present investigation provides additional data as to possible correlation of trimethylamine values of

[a] Contribution No. 703, Massachusetts Agricultural Experiment Station, Amherst, Massachusetts.

fish at various stages of decomposition to organoleptic tests, ammonia values, and aerobic bacterial counts. The effect of temperature, naturally occurring autolysis, and microorganisms on trimethylamine formation was also investigated.

Effect of Temperature on Trimethylamine Formation

Experimental. Samples of frozen swordfish, thawed and ground in a sterile food chopper to facilitate sampling, were stored in No. 10 cans (603 x 700) at temperatures of 24.4° C. (75° F.), 4.4° C. (40 °F.), and 0° C. (32° F.) until they spoiled. Analyses were made for trimethylamine by Dyer's *(5)* colorimetric method, for ammonia, by the aeration method recommended by Crooks and Ritchie *(3)*, and aerobic bacterial counts according to the method of Weinzirl and Newton *(14)*. Plates were incubated at 24.4° C. (75° F.) for four days. Results are shown in Figs. 1, 2, and 3.

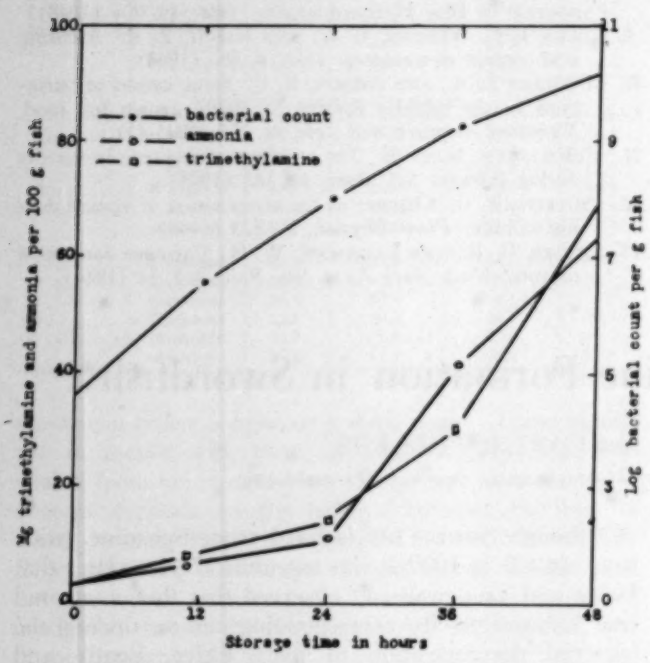


FIG. 1. Trimethylamine and ammonia values and aerobic bacterial count of frozen-thawed swordfish stored at 75° F. (24° C.).

Discussion of Results. During storage at 24.4° C. (75° F.), there was a sharp parallel increase in trimethylamine, in ammonia, and in bacterial counts. After 12 hours the samples were stale on a basis of organoleptic evaluation. At this time the trimethylamine value was 10 milligrams per 100 grams of fish. Fish considered stale were somewhat abnormal in odor, but not unfit for food. As spoilage progressed, the three values increased sharply. The odor of trimethylamine became most obnoxious and masked the detection of any ammonia odor. At 4.4° C. (40° F.) storage temperature, the trimethylamine value lagged, rising to 10 milligrams per 100 grams of fish on the ninth day of storage at which point the samples were stale. As decomposition progressed, the bacterial count and ammonia value reached approximately the same values as at 24.4° C. (75° F.) storage, but the trimethylamine value increased only to 39 milligrams per 100 grams of fish. Throughout the storage period the odor of trimethylamine was not nearly as pronounced at 4.4° C. (40° F.) as at 24.4° C. (75° F.). During the 0° C. (32° F.) storage period trimethylamine and ammonia values did not rise although the bacterial count did rise steadily. The samples were stale after 15 days of storage, and there was noted no odor of trimethylamine. At this stale stage of decomposition, the trimethylamine value was 3.5 milligrams per 100 grams of fish, and the ammonia value 4.8 milligrams per 100 grams of fish.

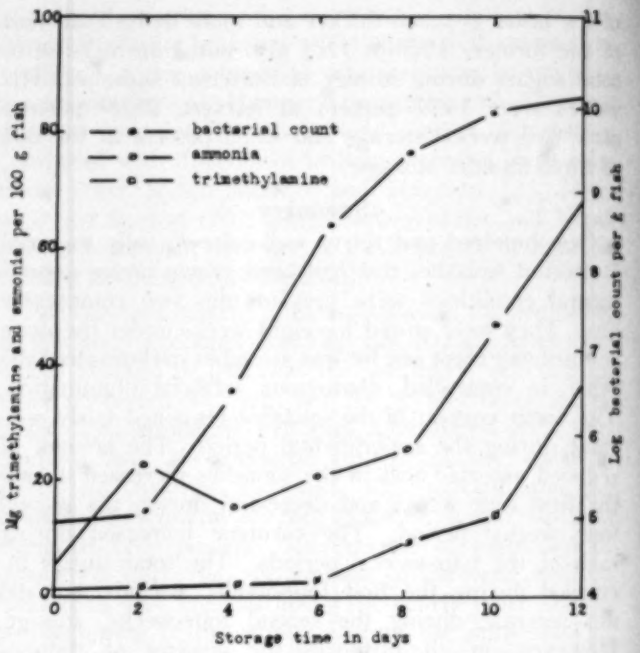


FIG. 2. Trimethylamine and ammonia values and aerobic bacterial count of frozen-thawed swordfish stored at 40° F. (4.4° C.).

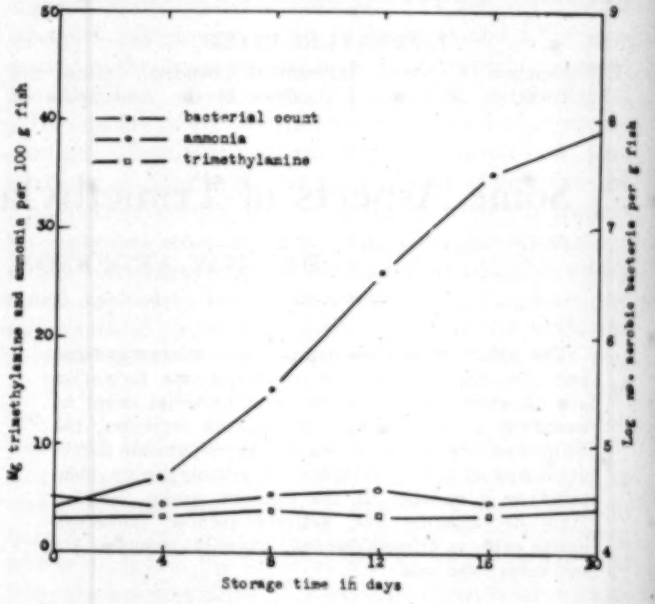


FIG. 3. Trimethylamine and ammonia values and aerobic bacterial count of frozen-thawed swordfish stored at 32° F. (0° C.).

Since the total bacterial count increased at the low temperature and the trimethylamine value did not, the

question arose as to whether the psychrophilic bacteria are capable of reducing the trimethylamine oxide of the fish muscle. Can bacteria which are capable of reducing the oxide at 24.4° C. (75° F.) also act at lower temperatures? There is also the question of whether reduction of trimethylamine oxide is due entirely to microorganisms or possibly to enzyme action in the fish muscle. Experiments bearing on these points were set up.

Effect of Microorganisms and Chemical Autolysis on Trimethylamine Formation

To further study conditions affecting trimethylamine production in fish flesh, a study was made of the effect of microorganisms and naturally occurring chemical autolysis of swordfish flesh on trimethylamine formation. Since trimethylamine oxide occurs naturally in fish flesh, it was decided to use the flesh as a source of the oxide. Because it was impracticable to obtain sterile fish flesh, a method was devised *(1)* for obtaining sterile muscle press juice containing the oxide but free from significant amounts of trimethylamine. The juice was sterilized by filtration methods. For the most part, this juice contained the same nutrients as fish flesh, supported luxuriant bacterial growth, and had the additional advantages of ease of handling and storage.

Samples of swordfish were allowed to spoil at the three temperatures previously used, namely 24.4° C. (75° F.), 4.4° C. (40° F.), and 0° C. (32° F.). When the fish was fresh, stale, and putrid at all three temperatures as determined organoleptically, samples were ground, diluted and plated on nutrient agar containing 2 percent fish juice. Transplants from colonies from these plates were streaked on agar slants. To test for the reduction of trimethylamine oxide, these cultures were individually inoculated into tubes of sterile muscle press juice, and incubated for four days at 24.4° C. (75° F.). Since the enzyme system of the sterile press juice was not inactivated during the sterilization procedure, uninoculated controls of the juice served as a means of testing the effect of chemical autolysis.

Discussion. Of the 50 various microorganisms isolated from swordfish samples at different stages of decomposition, only one rapidly reduced the trimethylamine oxide of the sterile press juice to trimethylamine. Although under the conditions of this experiment no other active trimethylamine oxide reducing strain was found, others may have been present. This organism, identified as an intermediate of the coliform group, was isolated from a stale sample of fish stored at 24.4° C. (75° F.). The uninoculated control tubes showed no presence of trimethylamine after the incubation period.

As a further check, all of the microorganisms were inoculated into a medium described by Wood and Baird *(15)* containing 0.1 percent trimethylamine oxide, and analyses for trimethylamine were conducted using the plug test also described by the same authors. In this medium, only the coliform intermediate described above was active. Sterile muscle press juice and pieces of sterile fish flesh when inoculated into this medium gave negative results.

Results show that the trimethylamine value of swordfish is dependent upon the storage temperature of the fish. The coliform bacterium which very rapidly reduced trimethylamine oxide at 24.4° C. (75° F.) had this reaction retarded from three to four weeks when stored at 4.4° C. (40° F.) and failed to reduce the oxide at all when stored at 0° C. (32° F.). Fish held at a low temperature as when packed in ice might conceivably have a low trimethylamine content in advanced stages of decomposition. Also, the trimethylamine value of fish is apparently dependent upon the presence of microorganisms capable of reducing the oxide found in marine fish flesh, since chemical autolysis plays no important role in reducing the oxide. This is in agreement with work referred to by Tarr *(11)*.

Summary and Conclusions. Although the total bacterial count of swordfish stored at low temperatures increases, the reduction of trimethylamine oxide to trimethylamine by the responsible microorganisms is greatly retarded.

Of fifty microorganisms isolated from samples of swordfish in various stages of decomposition after storage at 24.4° C. (75° F.), 4.4° C. (40° F.), and 0° C. (32° F.), a bacterium identified as a coliform intermediate, rapidly reduced trimethylamine oxide to trimethylamine. This microorganism was isolated from stale fish stored at 4.4° C. (40° F.).

It could not be shown that naturally occurring chemical autolysis reduced trimethylamine oxide to trimethylamine.

LITERATURE CITED

1. Anderson, D. W., and Fellers, C. R. Preparation of sterile fish muscle press juice for chemical and bacteriological studies. *Food Tech.* this issue (1949).
2. Beatty, S., and Gibbons, N. Measurement of spoilage in fish. *J. Biol. Board Can.* **3**, 77 (1937).
3. Crooks, G., and Ritchie, W. A study of the rate of decomposition of haddock at various temperatures as indicated by ammonia content. *Food Res.* **3**, 589 (1938).
4. Dyer, W. A color test for the measurement of sea fish by trimethylamine estimation. *Progress Report* Atlantic Fish. Exp. Sta., Halifax, N. S. **34**, 4 (1943).
5. Dyer, W. Amines in fish muscle. I. Colorimetric determination of trimethylamine as the picrate salt. *J. Fish. Res. Board Can.* **6**, 351 (1945).
6. Hillig, F. Personal communication (1949).
7. Labrie, A., and Gibbons, N. Studies on salt fish. I. The effect of salt concentration on preservation. *J. Biol. Board Can.* **3**, 5 (1937).
8. Poller, K., and Linnewah, W. The occurrence of trimethylamine in *Clupea harangus*. *Ber.* **59**, 1362 (1926).
9. Sigurdsson, G. Comparison of chemical tests for the quality of fish. *Ind. Chem. Eng. (Anal. Ed.)* **19**, 892 (1947).
10. Suwa, A. Extract of the flesh of fish. *Zentr. Physiol.* **22**, 307 (1909).
11. Tarr, H. L. A. The bacterial reduction of trimethylamine oxide to trimethylamine. *J. Fish. Res. Board Can.* **4**, 367 (1939).
12. Tarr, H. L. A. Trimethylamine formation in relation to viable bacterial population of spoiling fish muscle. *Nature* **142**, 1078 (1939).
13. Tarr, H. L. A., and Sunderland, P. Preliminary notes on the keeping quality of lightly smoked fish. *Progress Report Fish. Res. Board Can.*, Vancouver, B. C. **37** (1938).
14. Weinzirl, L., and Newton, E. Bacteriological analysis of hamburger steak with reference to sanitary standards. *Am. J. Pub. Health* **4**, 413 (1914).
15. Wood, A., and Baird, E. Reduction of trimethylamine oxide by bacteria. *J. Fish. Res. Board Can.* **6**, 194 (1943).

Preparation of Sterile Fish Muscle Press Juice for Chemical and Bacteriological Studies[a]

DAVID W. ANDERSON, JR., AND CARL R. FELLERS
Department of Food Technology, University of Massachusetts, Amherst, Massachusetts

A sterile filtration procedure for obtaining sterile fish muscle press juice without resorting to heat or dilution is described. This sterile muscle press juice is very convenient for the study of biochemical reactions of bacteria and chemical autolysis in a natural environment.

It is difficult and often most impracticable to obtain sterile sections of fish for use in making bacteriological and chemical observations. For many purposes the fish muscle press juice serves equally well. It is difficult to obtain sterile juice without either excessive dilution or filtration followed by sterilization by heat. This alters natural conditions. A procedure for obtaining sterile muscle press juice without resorting to sterilization by heat was derived as follows:

Fresh fish or partially thawed frozen fish was ground in a food chopper and kept at refrigerator temperature thereafter. Portions of about two to three hundred grams in weight, were wrapped in canvas, and were pressed in a Carver laboratory press.

The press juice was then centrifuged for five minutes to separate the oil and sediment. The clear layer below the oil was pipetted into clean centrifuge tubes and again centrifuged.

A mat of asbestos, one-eighth inch in thickness, was formed on a Buchner funnel and the juice was passed through this mat using suction. It was necessary to make frequent changes of the mat owing to the formation of a gelatinous layer on the mat surface which retarded filtration. After filtering through the asbestos, the juice again was filtered, using a Dicalite asbestos mat. This was made by forming a one-quarter-inch layer of washed Dicalite on a similar asbestos mat. Juice which passed through this filter was clear, greenish-yellow in color, and passed readily through a bacteriological filter candle.

A liter suction flask, fitted with a Berkefeld candle and clamped suction hose, was sterilized. The suction hose was then connected to a sterile three-way glass petcock. One of the two remaining petcock outlets was attached to a trap and vacuum pump. The other outlet was attached to a cylinder twelve inches long, one inch in diameter, tapering to one-eighth-inch diameter tubing at each end. This cylinder was packed with oil soaked glass wool and then sterilized. Its purpose was to insure the entrance of sterile air when releasing the vacuum formed in the suction flask. During all filtering operations, flasks were packed in ice baths to keep the juice cold, thus minimizing enzymatic and bacterial activity.

After filtering the juice through the bacteriological filter, the juice was aseptically tubed or placed in flasks and stored at 0° F. (— 22° C.). This sterile juice supported luxuriant bacterial growth, and afforded an opportunity to study naturally occurring chemical autolysis in a natural environment. The authors found this sterile press juice very convenient for the study of biochemical reactions of bacteria.

[a] Contribution No. 700, Massachusetts Agricultural Experiment Station, Amherst, Massachusetts.

Determination of Color of Unclarified Juices by Reflectometer[a,c]

OLIVER J. WORTHINGTON, ROBERT F. CAIN[b], AND ERNEST H. WIEGAND
Food Technology Dept., Oregon State College, Corvallis, Oregon

Techniques of a quantitative, objective method for the determination and specification of the color of unclarified juices by reflection meter are described. The method is rapid, inexpensive and involves no color matching. Results include turbidity effects and are in tristimulus units, i.e. are on the basis of color as viewed by the consumer.

There is need for an objective method of analyzing and specifying the color of food products for grading and control purposes. This is demonstrated in the P. M. A. and other grade specifications where the color description is usually in such terms as "bright typical color."

Now it is evident how non-quantitative such grading must be, at its best, since it depends upon extensive and intensive experience and color skill in each commodity. An attempt to improve this in the case of grapefruit juice was made about 1939 by Maerz and Paul *(8)* designations and such statements as: Grade C may not be darker than Plate 10, J-2. This type of description was removed from the grade standards possibly for one thing because there would be differences of opinion concerning whether a sample were darker or not. Various combinations of the three color attributes, *hue*, *value* or brightness, and *chroma* or saturation may give the im-

[a] Published as Technical Paper No. 570 with the approval of the Director of the Oregon Agricultural Experiment Station. Contribution of the Department of Food Technology.

[b] Present address: Horticulture Dept., Texas A. & M. College.

[c] Presented at the Annual Meeting of the Northern California Section of the Institute of Food Technologists, Dec. 2, 1948, Albany, California.

pression of darkness. Actually, all samples of freshly prepared as well as canned grapefruit juice which we have examined by the objective method to be described below, had attributes of being darker than the grade C Maerz and Paul designation.

Color matching skill, if not an insurmountable difficulty, is almost so when there is taken into account the two different types of surfaces and the desirability for having them in juxtaposition as in a split field occular. To a degree these difficulties can be overcome by use of the Munsell system with rotating disks or their equivalent. Differences between the sample and the color disks can be assessed by making changes in the disk percentages and noting improvement or worsening of color match. It would not be pertinent to go into the intricacies of this determination here. It is sufficient to say that the apparatus is expensive, too cumbersome for grading or control work and is presently unavailable.

The chemist, when first confronted with the problem of color designation in juices, is likely to revert at once to the spectrophotometer or the filter electrophotometer. Color measurement by absorptometry requires clear solutions. In clarifying a cloudy juice its whole aspect is changed and it bears little resemblance to the article of commerce. In consumer acceptance studies it goes without saying that one should measure the juice as is. It is true that by correlation studies, the absorption characteristics of a clear juice may, by going through two or three correlation factors, give a precise measure of the cloudy juice. Such complex basic studies have been made by Sondheimer and Kertesz *(7)* for strawberry products but not for most commodities. Also practical considerations require a description in terms of a few figures rather than a curve. Again, a spectrophotometric curve, of itself, does not tell the color of a juice as seen, since that depends upon the illuminant, the sensitivity of the eye and color blending by additive effects. In fundamental studies on pigment reactions, and in the quantitative estimation of concentrations, absorption instruments are desirable—in fact, necessary.

We are here reporting upon the adaptation of the photoelectric reflectometer for the quantitative assay of the color of cloudy juices. A measurement can be made by an unskilled color-blind laboratory technician in ten minutes. Such an instrument is the Photovolt Reflectometer, originally intended for painted panels, for papers or for textiles. The cost is about that of an inexpensive filter electrophotometer.

The reflection meter consists of two units: The instrument proper with galvanometer and controls, and the search unit connected by cable which contains the light source and measuring photocells. Fig. 1 shows a cross-ection of the search unit which is a cylinder of about 5″ high and 3″ in diameter. The opening to which the surface being analyzed is exposed is about ⅝″ in diameter. The incident beam is perpendicular to the surface and the diffusely reflected light is "viewed" at an angle of about 45° by the measuring photocell but with infinite planes due to the receiving area of the photocell which is a ring about 1″ broad.

Principle: The search unit is furnished with three tristimulus glass filters to be used successively. The glasses are designated amber, green, and blue and transmit according to the specifications of the National Bureau of Standards *(3)*. The International Congress on Illumination in 1931 *(4)* set up the "ICI Standard Observer" tristimulus notations in tables so that a color as seen by the average observer will have a certain numerical designation which describes that color universally and precisely and which describes no other color. Munsell disks have been rated in terms of the three ICI notations, X, Y, Z, and with these filters the results can be computed in ICI terms or Munsell terms.

Procedure: We have found that for a juice like fresh or canned grapefruit juice, the minimum size container should be 3″ in diameter and 3″ high. In this case, none of the incident light is reflected from the walls of the container. Thus any kind of 8 oz. can is not satisfactory. On the borderline of usefulness would be can sizes 300, 300X, and No. 1 tall. If the juice sample were not more cloudy than above, i.e., as non-transmissable as the grapefruit juice due to reflectance and/or absorption it would be well to use one of the No. 2 can sizes. If the juice were less cloudy, the minimum size of container would have to be determined. Since the container must be level full, a lipped beaker cannot be used. If it is desired to make a determination on a single No. 2 can of juice, a few glass disks can be dropped to the bottom to raise the liquid level to the top, after stirring.

Since the reflectometer (Fig. 2) was not intended for liquid surfaces, it was necessary to construct the

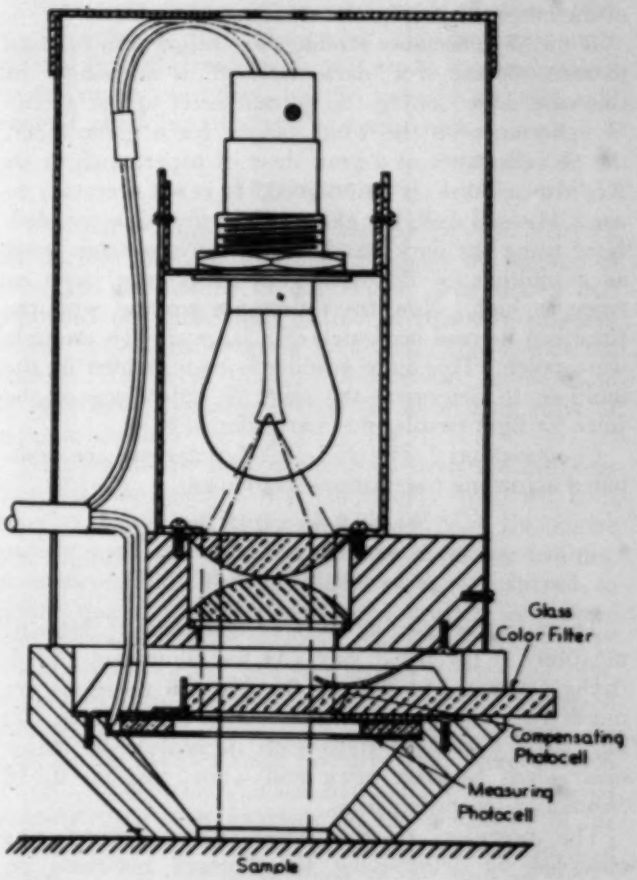


FIG. 1. Cross Section of Reflection Meter Search Unit.

FIG. 2. Photovolt reflection meter in use with support and positioning collar showing search unit and sample.

collar-like support for the search unit. This positions the unit with the light beam perpendicular to the surface, reduces stray light, and if the can is exactly filled, the collar causes the distance from glass filter to liquid surface to be always the same.

Upon inserting the amber filter, the search unit is placed on the calibrated white enamel plaque and the dial reading for % reflectance standardized upon the proper calibration number. The reading is then obtained and recorded, after careful positioning of the unit and collar on the can of juice. This is then repeated for each of the other two tristimulus filters.

If the % reflectance readings are below zero or close to zero, the use of a "dark standard" is necessary. In this case, after setting the galvanometer at the proper % reflectance on the white plaque for a given filter, the % reflectance of a gray sheet of paper, such as an N5/Munsell disk, is determined. It is not necessary to use a Munsell disk, but glossy paper should be avoided. Now using the dark standard, the galvanometer is set as a multiple of its determined reflectance, such as twice as high. Now the reflectance reading with the juice can be read accurately if a large enough multiple were taken. This juice reading is then divided by the multiple to determine the true % reflectance of the juice for light passing that particular filter.

Computations: The ICI, XYZ notations are computed according to equations as follows:

$$X = 0.8\,A + 0.18\,B$$
$$Y = G$$
$$Z = 1.18\,B$$

These can be used as such, or converted to Munsell notations in the usual way *(5)* for Illuminant "C"—daylight values. Ordinarily the Munsell notations are much more useful with the spectrum divided into 100 *hue* steps (or more steps with decimals), 10 major *value* steps between black and white, and up to 18 *chroma* or saturation steps.

The precision of the reflectometer method was observed by determining the Munsell notations on known Munsell disks. These are listed in Table 1.

TABLE 1

Precision of Reflection Meter on Munsell Disks

Disk	By Reflectometer	% Error Hue	% Error Value	% Error Chroma
3GY7.5/11.2	3.8GY7.5/11.5	0.8	0.0	1.8
3GY7.5/11.2	3.75GY7.5/11.0	0.75	0.0	1.2
10GY5/8	10GY4.8/8.6	0.0	2.0	3.1
5GY6/8	6GY6.1/7.9	1.0	1.0	0.6

The Munsell notations for diverse commercial juices are found in Table II. This indicates the range of usefulness of the method. Munsell notations are already used rather generally for color specification. They are official for the American Standards Association *(1)*. Among food products, the P. M. A. grades for canned tomatoes and tomato products are delineated by the use of Munsell disks. Different samples of a product, of different manufacture, grade, storage life usually differ markedly in only one color attribute or at the most in two attributes. Therefore in studying the effects of various factors upon the consumer acceptability of colors, the factor can often be plotted against a color attribute such as hue in order to relate the two. Such has been reported in the literature of non-food products by Nickerson *(6)* and for green beans by one of our graduate students *(2)*. Work is underway in this laboratory to show possible grade demarkations of specific juices and to show color changes due to processing and storage. The reflection meter also gives objective, precise, and reliable notations for powders. Also underway are studies on the use of the reflection meter for sundry fresh or canned solid commodities.

TABLE 2

Results of Color Determinations
(In order of hue)

Vegetable Juice Cocktail, Brand A	7R2.6/10.7
Tomato Juice	8.7R2.74/8.11
Carrot Juice	8.7YR5/9.2
Vegetable Juice Cocktail, Brand B	2.9YR2.5/8.15
Bottled Orangeade (Color added)	0.8Y2.61/2.76
Unclarified Apple Juice	2.2Y2.5/3.7
Blended Citrus Juice, Brand A	6.2Y3.92/3.4
Blended Citrus Juice, Brand A	9Y3.84/3.66
Cream of Chicken Soup Conc.	7.0Y8/8.6
Grapefruit Juice, Brand A	7.8Y3.6/1.0
Orange Juice, Brand A	1.30GY4.43/4.46
Orange Juice, Brand B	1.4GY4.22/5.8
Apricot Nectar	1.5GY3.8/8.1
Apricot Nectar bubbled 24 hrs.	1.6Y3.5/5.6
Blended Citrus Juice, Brand B	2GY3.5/2.5
Comminuted Apple	3GY5.6/3.8
Canned Lemon Juice, after 18 hrs.	5.3GY3.9/2.1
Grapefruit Juice, Brand C	2.75G3.21/10.9
Grapefruit Juice, fresh	3.1G2.14/3.9
Grapefruit Juice, Brand B	7.5G3.41/1.78

Summary

Techniques for the use of the photoelectric reflectometer in the determination and specification of the color of unclarified juices are described. The method has the following characteristics:

1. It specifies the color as seen rather than being an analysis of any constituent or of the color as constituted. The results may be reported in Munsell terms or in terms of the International Committee on Illuminants.

2. The personal factor in the analysis is entirely removed, so that the analyzer may be color-blind in fact.

3. The results are reproducible with precision and

being in standardized terms are directly comparable with any other juice or in fact with any other color.

4. No dilutions are involved and the total effect of color and turbidity is included.

5. The method is suitable for grading, since it is simple, inexpensive, and rapid in operation.

6. The method is equally useful for powders and studies are in progress for the use of the method for the determination of color of other solid food products, fresh, canned or otherwise processed.

LITERATURE CITED

1. American Standards Association, Z44-1942. *Specification and Description of Color* (1942).
2. Bam, S. G. Color measurement and its relation to grading of canned and frozen green beans. *M.S. Thesis,* Oregon State College (1948).
3. Hunter, R. S. Photoelectric tristimulus colorimetry with three filters. National Bureau of Standards. *Cir.* C429 (1942).
4. Judd, D. B. The 1931 I. C. I. standard observer and coordinate system for colorimetry. *J. Optical Soc. Amer.,* 23, 359 (1933).
5. Newhall, S. M., Nickerson, Dorothy, and Judd, D. B. Final report of the O. S. A. subcommittee on the spacing of the Munsell colors. *J. Optical Soc. Amer.,* 33 (7) 385 (1943).
6. Nickerson, Dorothy. Color measurement, and its application to the grading of agricultural products. U. S. Department of Agriculture, *Misc. Pub.* 580 (1946).
7. Sondheimer, E., and Kertesz, Z. I. Anthocyanin pigments: Colorimetric determination in strawberries and strawberry products. *Analyt. Chem.* 20 (3) 245 (1948).
8. U. S. D. A., Agricultural Marketing Service. Tentative U. S. standards for grades of canned grapefruit juice. *Food Ind.* 11, 619 (1939).

Loss of Reduced Ascorbic Acid From Riboflavin-Enriched Mares' Milk

ARTHUR D. HOLMES

Massachusetts Agricultural Experiment Station, Amherst, Mass.

The results obtained by assaying mares' milk, which had been enriched with varying amounts of riboflavin, have led the author to conclude that the loss of reduced ascorbic acid is not principally due to the riboflavin content. The rate of ascorbic acid loss is graphically demonstrated.

Milk, as it is drawn from the cow, is a moderately rich source of reduced ascorbic acid, and in the quantities consumed it could meet the requirements of man, but in the interval that elapses before it reaches the ultimate consumer a large part of the reduced ascorbic acid is lost. For instance, Gunsalus and Hand *(2)* have shown that the amount of reduced ascorbic acid in commercial cows' milk decreased from 14.9 mg. per liter to 1.7 mg., i.e., 88% during six days' storage. Other workers have reported similar losses of reduced ascorbic acid during the first few days after milk is obtained from the cow. On the other hand, Holmes and Jones *(3)* in a study of the stability of reduced ascorbic acid in mares' milk found that only about 8% of the original amount of reduced ascorbic acid disappeared from mares' milk during a comparable period. Obviously, one may question why reduced ascorbic acid disappears from cows' milk ten times as fast as from mares' milk when both are stored under the same conditions. In an attempt to accumulate data bearing on this question, Holmes *(4)* considered the possible effect of the difference in lactose content of cows' and mares' milk and added 15 gm. and 30 gm. of lactose per liter to cows' milk. Samples containing these two amounts of lactose and a control sample were prepared each week for 15 weeks and stored in the dark at 10° C. Each sample was assayed for five consecutive days after the addition of lactose. The reduced ascorbic acid disappeared from the lactose enriched samples at practically the same rate as from the controls. These data indicated that the high lactose content of mares' milk is not the primary factor that causes a slower rate of reduced ascorbic acid destruction in mares' than in cows' milk.

Since cows' milk contains much more riboflavin than mares' milk and reduced ascorbic acid disappears more rapidly from the cows' milk, this study was undertaken to determine the effect, on the reduced ascorbic acid content, of adding riboflavin to mares' milk.

Experimental

The milk used in this study was pooled milk collected on thirteen Monday mornings between the middle of June and the middle of September. The mares that produced the milk were grazed in intervale pastures where native grasses grew luxuriantly throughout the season. They were young, well-developed animals and in excellent physical condition for producing milk of superior quality.

As soon as the milk was drawn from the different mares it was taken to the laboratory, combined in a glass container of sufficient size to hold the entire amount with due allowance for the excessive frothing of mares' milk. The combined milk was stirred to insure thorough mixing and then divided into three equal portions. To one portion 2 mg. per liter of U. S. P. riboflavin was added, and to a second portion the riboflavin was added at the rate of 4 mg. per liter. The third portion of pooled mares' milk served as a control. As soon as the samples were prepared they were assayed for reduced ascorbic acid and subsequently were assayed at twenty-four-hour intervals for the remainder of the five-day experimental period. During the experimental period the samples were stored in the dark at 10° C. The amount of reduced ascorbic acid in the riboflavin

*Contribution No. 705, Massachusetts Agricultural Experiment Station.